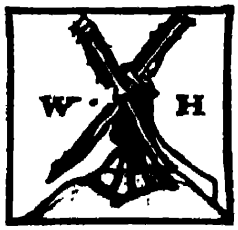
SCIENCE AND EDUCATION

SCIENCE AND EDUCATION

LECTURES DELIVERED AT THE ROYAL INSTITUTION OF GREAT BRITAIN

EDITED WITH AN INTRODUCTION BY

SIR E. RAY LANKESTER, K.C.B.



LONDON : WILLIAM HEINEMANN

London : William Heinemann, 1917

INTRODUCTION

THE present volume is a reprint of one published in 1855, and now out of print, consisting of seven lectures delivered at the Royal Institution of Great Britain in 1854 by seven of the most distinguished men of science of that day. The purpose of the Managers of the Royal Institution was to set before the public the views of scientific men as to the importance of making Natural Science an integral part of the education of all classes. Sixty-two years have passed and we are still so far from having carried out the views of those lecturers that a great outcry has arisen in this country—now suffering under the pressure and difficulties of warfare—to the effect that there has been "neglect of science," both in the management of great public interests and in private enterprises. It is maintained that the nation is in imminent danger owing to the ignorance of and contempt for Natural Science in the governing class, in the manufacturing and commercial classes, and among the people generally. It is pointed out that the only remedy for this is a complete change—a reformation in the education given in our schools and universities. The effort to bring about such a change began sixty-two years ago with the lectures here reprinted—and it is interesting to look back at the reasons for reform put forward by those lecturers so many years ago and to consider what value they have at the present day and why it is that they and the arguments and efforts of later reformers have had so little result. For it is the fact that though some improvement has been made, it is very small. Our school education, especially that of the great public schools and that rewarded and encouraged by the universities of Oxford and Cambridge, does not yet comprise as a necessary integral part the study of Natural Science. Natural Science is still treated as a superfluity, an "extra," tolerated, but

misunderstood and misdirected (as is natural enough) by the devotees of the established old-fashioned and curious "classical curriculum," which it must eventually completely replace. The reasons which have led to the consumption of so vast a proportion of the time of the youth of the well-to-do class in a clumsy and ill-contrived attempt to force it into familiarity with the actual writings of Latin and Greek authors—an attempt which is almost invariably unsuccessful—are not far to seek. Three hundred years ago a well-educated "gentleman" must read Latin if he would read anything and must write it too. This is convincingly set forth by the father of the present Minister of Education in a paper contributed by him to a volume of *Essays on a Liberal Education*,* which contains several other essays of a most instructive character for those who are to-day considering the question of Educational Reform. Among these is an invaluable chapter "On the History of Classical Education" by the late Charles Stuart Parker, M.A., Fellow of University College, Oxford, which furnishes to-day—as it did when written—information of fundamental importance as to how it has come about that this country is subjected to the preposterous and disastrous tyranny of "classical education." The genial and gifted Lord Houghton (Monckton-Milnes), in the essay contributed by him "On the Present Social Results of Classical Education," deplores the fact (and none could speak with greater authority than he) "that the whole of the boyhood and the greater part of the youth of the higher classes of our countrymen should be occupied with the study of the language, history, and customs of two nations which have long disappeared from the surface of our globe, and which, but for the common conditions of all humanity, have no more relation to us than the inhabitants of another planet." He, a scholar and man of letters, asks whether "the imagined attributes of a classical education are not referable to circumstances and treatment with which classics as such have nothing whatever to do—and whether the most enlightened advocates of the retention of the system are not unconsciously affected by a powerful literary superstition?" He makes the very significant observation that "it is as the proper and recognized education of the governing classes, the honourable accomplishment of all aristocracy, that the classical

* Macmillan, 1867.

teaching endures so firmly, even now when it has ceased to be the mysterious speech of the Church and when it is no longer the authoritative exposition of Law. For as soon as it became the qualification of a gentleman to read and write at all, it was Latin that he read and wrote."

After showing how small is the amount of classical learning carried over from school and college into later life by those whose whole youth is recklessly sacrificed to "a classical education," Lord Houghton says: "However imperceptible may be the effects of classical training in after-life, either in manners or in mind, as long as the fashion of the education endures, our higher classes will continue to subject their children to it, and the large portion of society which desires, at any cost, to give their progeny what seems to them the best start in life will follow the example. Whilst a boy is placed, on his arrival at school, according to his classical attainments, the preliminary classical teaching becomes necessary, whatever be the sacrifice of other natural, opportune, or more available instruction." "It will," he continues, "require some very strong impulse to decide what may be called the upper stratum of the middle class to accept for their families any education which almost appears a descent in the social scale. And yet it is precisely this class which is the most palpable sufferer under the present system. . . . When the young manufacturer or banker begins what is to be the real business of his existence, he leaves irrevocably behind him every object to which his ten (or more) early years have been devoted, retaining little beyond some taste in which only the idle or the independent can indulge with impunity, and a certain dim conceit of his own superiority over his fellows, who have only received a commercial training."

* * * * *

"There are too many flagrant examples in the history of the human mind of the persistent adherence, not only of public opinion and private judgment, but of the religious conscience and the moral sense, to forms and ceremonies after the belief on which they were founded have faded into shadows, to permit the hope that any amount of negative experience will bring about a reformation in the matter we are now considering. It is solely to a growing conviction of the necessity of larger and wiser instruction of our governing classes, if they are to remain our governors, that we must look as the source of any beneficial change."

After sketching the extreme self-satisfaction with which we regard the character of the present English gentleman, and the notion that he is an ideal of humanity which it is almost sinful to desire to improve or transcend, and that if he in his youth were taught more or otherwise than he learns at present some mysterious degradation would inevitably ensue, Lord Houghton declares that there never was a greater confusion of *post hoc* with *propter hoc* than the theory that the English gentleman's actual excellent characteristics have anything to do with the method of instruction which has been imparted to him. "It is admitted," he says, "that he may become a landed proprietor without a notion of agriculture—a coal-owner without an inkling of geology—a sportsman without curiosity in natural history—a legislator without the elements of law; it is assumed that he may frequent foreign countries without having even a convenient intimacy with their language, and continually incur that ridicule which is especially disagreeable to his nature; and yet, in the face of all these admissions,* every attempt to supply these deficiencies is regarded as little less than revolutionary."

Such is the indictment of "the classical education" drawn up fifty years ago by a great "man of the world," one who knew perhaps more intimately than any man of his day, or of later years, both what he was condemning and what he desired to substitute for it.

We are frequently told that of late years there have been great changes in these matters, that science and modern studies have been "introduced" into the great public schools. It is, on the contrary, the fact that "the classical education" still dominates, still continues its hopeless and injurious sacrifice of the golden hours of youth to its ill-contrived methods of teaching and its wasteful and unsuccessful attempt to develop the intelligence of English boys by forcing upon them, necessarily to the exclusion of other subjects, a mechanical study of the language, literature, and history of the ancient Greeks and Romans. This system continues, although it is universally admitted that it completely fails to impart even a modicum of knowledge of these subjects—worthless though it would be

* And we might add to this list his ready admission of and satisfaction with the fact that he knows nothing of the beauties of the English language and its literature.—E. R. L.

were it gained—to the great majority of those submitted to it.

If one wishes to know what is the amount of the concession which has been made in our great schools to the demand for education in the Natural Sciences, one has only to note how small is the number of hours a week assigned to those sciences *for all boys in the school*, how few is the number of masters employed, how inferior their position, how little is the reward and encouragement for scholars, and how small the pay accorded to all concerned in Natural Science as compared with the corresponding figures relating to the arrangements made for the dominating, monopolizing, "classical" studies.

The Natural Sciences will not obtain the attention and position in schools which is necessary for our national welfare until the ancient traditional "classical curriculum" is *not* merely modified and reformed but literally swept away. This, of course, would not in any way interfere with the serious study in this country of classical literature and classical archæology, but, on the contrary, assist its development.

The most interesting and in many respects the most valuable of the seven lectures now reprinted is that by the great Faraday. I should have been content to reprint this lecture by itself, but Mr. Heinemann was willing to reproduce the whole series. Not the least of the features of interest attaching to these lectures is the presentation in each of them of the conclusions and opinions held by an authority in his subject three-quarters of a century ago. In regard to some of the subjects—for instance, Chemistry treated by Professor Daubeny of Oxford, and Physiology dealt with by Sir James (then Mr.) Paget—the progress of knowledge has been so great in the interval that much of what is said by the lecturer is not precisely what he would say were he speaking to-day. Facts have been ascertained and theories established to which he would have made allusion. But the spirit and purpose of his discourse is none the less of value to-day as it was when given.

It would be foreign to my present object to annotate the lectures of these great advocates of educational reform so as to show in what respects investigation has progressed since their day. It was my privilege in early years to listen to the

teaching of some of them and to know all of them as friends of my father. I am glad to be able to reproduce to-day their testimony in favour of the reform in education which consists in giving a leading place in it to a well-considered study of Natural Science—whilst abolishing altogether the hopeless waste of time and effort arising from the bad methods and mistaken purpose of the traditional study of Latin and Greek.

In the case of Faraday's lecture on "Mental Education," I have been so much impressed by its beauty, interest, and value that I have looked up and made notes relating to one or two matters which are referred to in it, but are obscure to a modern reader—such, for instance, as "The Pasilalinic Compass." I have also, with the aid of my friend Mr. Mark Barr, written some notes which will render some of Faraday's references to his own researches intelligible. These several notes are referred to in the text by letters of the alphabet and are printed at the end of the lecture.

Faraday was a vigorous opponent of the various fanciful notions as to table-turning, spirit-rapping, and animal magnetism current in his day. The modern "occultist" will not hesitate to endeavour to weaken Faraday's "authority" in that opposition by pointing to the fact that he is careful "to claim an absolute distinction between religious and ordinary belief," and that he says, "I shall be reproached with the weakness of refusing to apply those mental operations which I think good in respect of high things to the very highest."

Let me at once plainly say that in the Court of Science evidence as to personal authority is not admitted.

The conclusiveness of an experimental demonstration and the value of the experimental method are not affected either by the religious beliefs or private opinions of the individual to whom we are indebted for the demonstration, provided that it *is* a demonstration. The opinions of Sir William Crookes, of Sir Oliver Lodge, and the late Dr. Russel Wallace with reference to so-called "spiritualism" have not in the smallest degree lessened the value of their contributions to Chemistry, Physics, and Zoology.

E. RAY LANKESTER

October 2, 1 16

BRIEF BIOGRAPHIES OF THE LECTURERS

DAUBENY, CHARLES GILES BRIDLE, chemist and botanist, was born in Gloucestershire in 1795, and educated at Winchester and Magdalen College, Oxford, where he became Professor of Chemistry and also of Botany. Daubeny devoted himself chiefly to the study of natural phenomena in their relation to chemical science. His chief work is *A Description of Active and Extinct Volcanoes* (1826), but he wrote also on the Atomic Theory, on Agriculture and Climate, as well as many papers on botanical subjects. He died in 1867.

FARADAY, MICHAEL, was born in London in 1791. His father was a blacksmith and he often spoke of his love for a smith's shop and the work of the forge and hammer. At the age of 13 he was apprenticed to a bookbinder, but becoming interested in science, he attended lectures at the Royal Institution, and in 1813 became laboratory assistant to Sir Humphry Davy. He soon began research work on his own account, and a series of experiments on chlorine compounds and the liquefaction of gases led to his discovery of principles of great importance. In 1827 he succeeded Sir Humphry Davy as Fullerian Professor of Chemistry, a position which he retained until 1865.

Faraday made many discoveries in chemistry and experimental physics, but the great work of his life is the series of experiments which, for forty years, he carried on in the domain of electro-magnetism. His discoveries were of great value and have laid the foundations of our knowledge of electricity. It was Faraday's discovery that an electric current is induced by the rotation of a magnet in the neighbourhood of an induction coil which led to the invention of the dynamo. Michael Faraday was a master of clear and lucid exposi-

tion, and his lectures at the Royal Institution are models of simplicity and happy illustration. He held very high what he spoke of as " the honour of a philosopher." He died at Hampton Court in 1867.

HODGSON, WILLIAM BALLANTYNE, educational reformer and political economist, was born at Edinburgh in 1815, the son of a printer. He entered the Edinburgh High School, and after working for some time in a lawyer's office proceeded to Edinburgh University. In 1844, after a period spent in lecturing on literature, education, and phrenology in various towns of Scotland, he became principal of the Liverpool Institute, and in 1847 went from there to the Chorlton High School, Manchester, where he remained until 1851. He lectured on economics at the Royal Institution in London and was examiner in political economy in the London University from 1863 to 1868. In 1871 he returned to Edinburgh to fill the new chair of commercial and political economy and mercantile law which had been founded very largely as a result of his own efforts, and this post he held until his death in 1880. He was president of the Educational Institute of Scotland in 1875.

LATHAM, ROBERT GORDON, M.D., was born in 1812, and educated at Eton and King's College, Cambridge. He studied philology in Hamburg, Copenhagen, and Christiania, and in 1839 was elected professor of English Language and Literature in University College, London. Some years later he entered the medical profession and obtained the degree of M.D. at the University of London, but he soon abandoned medicine and devoted himself almost entirely to his favourite pursuits of ethnology and philology. Latham was the author of many works on the English language. He died at Putney in 1888.

PAGET, SIR JAMES, Bart., one of the greatest surgeons and pathologists of modern times, was born at Yarmouth in 1814. He was President of the Royal College of Surgeons in 1875, Bradshawe Lecturer in 1882, Sergeant-Surgeon to Queen Victoria and Consulting Surgeon to King Edward VII, when the latter was Prince of Wales. His two chief works are ***Lectures on Surgical Pathology*** (1853) and ***Clinical Lectures*** (1875). He died in 1899.

TYNDALL, JOHN, physicist, was born in Ireland in 1820, the son of a small tradesman. After working for some years on the ordnance survey, and as a railway engineer in Manchester, he went to Germany, where he studied at Marburg and in Berlin, carrying on researches in physical science. He was elected F.R.S. in 1852, and in the following year became professor at the Royal Institution. A visit to the Alps, made in company with Professor Huxley in 1856, resulted in the famous work on the structure and motion of glaciers, and in 1859 he began those investigations into the phenomena of radiation upon which his fame chiefly rests. Tyndall was an extremely able lecturer and writer, his style being distinguished by vigour and lucidity of expression. His best-known works are *Heat Considered as a Mode of Motion* (1863), *Fragments of Science for Unscientific People* (1871), and *Hours of Exercise in the Alps* (1873), but he wrote many other books, including volumes on Light, Sound, Electricity, and the Forms of Water in Clouds, Rivers, Ice, and Glaciers. His works have been translated into most European languages. Tyndall died in 1893.

WHEWELL, WILLIAM, D.D., was born at Lancaster in 1794, the son of a joiner. He was educated at the "Blue School" in Lancaster, and afterwards at Heversham Grammar School, whence he proceeded, as an exhibitioner, to Trinity College, Cambridge. His career at the University was exceptionally brilliant. He gained the Chancellor's medal for the English prize poem in 1814; two years later he graduated as second wrangler and second Smith's prizeman, and became a Fellow and Tutor of Trinity. In subsequent years he filled the chairs of Mineralogy and Moral Philosophy at Cambridge. In 1841 he married and became Master of Trinity, and in 1855 was Vice-Chancellor of the University. He was a prolific and lucid writer and lecturer, producing works on astronomy, electricity and magnetism, moral philosophy and ethics. His most valuable and readable book is that on *The History and Philosophy of the Inductive Sciences*. He died at Trinity in 1866.

CONTENTS

ON THE INFLUENCE OF THE HISTORY OF SCIENCE UPON INTELLECTUAL EDUCATION

A LECTURE DELIVERED AT THE ROYAL INSTITUTION OF GREAT BRITAIN, BEFORE H.R.H. PRINCE ALBERT

By WILLIAM WHEWELL, D.D., F.R.S.
Master of Trinity College, Cambridge

The managers of the Royal Institution having determined to provide for their members and others a series of Lectures upon Education, and having expressed their wish that I should offer to the audience here assembled any views which may appear to me suited to such a purpose, I venture to do so, relying upon an indulgence which I have more than once experienced here on similar occasions. Of such indulgence I strongly feel the need, on various accounts, but especially on these *two*—first, that being so unfrequently in this metropolis, I do not know what trains of thought are passing in the minds of the greater part of my audience, who live in the midst of a stimulation produced by the lively interchange of opinion and discussion on the prominent questions of the day, to one of which what I have now to say in a great degree refers; and next, that in this hall, where you are accustomed to listen to the most lively explanations of scientific discoveries, illustrated by the most skilful and striking experiments, *I* have to present to you a series of remarks on subjects more or less abstract and vague, without being able to aid my exposition by anything addressed to the eye. The pictures which words can give of abstruse and general mental conceptions, when they alone form a diorama on which the mental eye of an assembly is to be directed for a whole hour, always appears to me to be in great danger of fading away into a dream of cloudland or a vacant blank. However,

as to that point, I have an advantage in speaking on the History of Science, which is my present subject in this room. To those of you who are in the habit of coming here, the walls must appear, from their customary aspect, to be hung with pictures which illustrate my theme. The striking facts in the history of science which you have presented to you in this place, week after week, are illustrations, in particular cases, of the general views which I have to offer to you; and if such expressions as *experience* and *theory*, *discovery* and *generalization*, *Baconian ascents* to comprehensive *axioms*, and *descents* thence to wonderful *works*—if such expressions be in danger of being *to others* vague and empty sounds, to *you* they will be, I may trust, all enlivened and embodied by what you have again and again seen here.

The subject on which I am desirous of making a few remarks to you at present is this: *The Influence of Scientific Discovery upon Intellectual Education*—the influence of the scientific discoveries of any period upon the intellectual education of the succeeding period; the influence, that is, of the intellectual achievements of one or two gifted men, at various epochs of the world's history, upon all those persons, in the next succeeding generations, who have aimed to obtain, for themselves or for their children, the highest culture, the best discipline, of which man's intellectual faculties are capable. I wish to show that there has been such an influence, and that it has been great at all periods; that is, at all those periods of intellectual energy and activity which come within the conditions of the terms;—all periods which have been periods of *discovery*. I wish to show that this influence has been so great that its results constitute, at this day, the whole of our intellectual education;—that in virtue of this influence, intellectual education has been, for those who avail themselves of the means which time has accumulated, progressive;—that our intellectual education now, to be worthy of the time, ought to include in its compass elements contributed to it in every one of the great epochs of mental energy which the world has seen;—that in this respect, most especially, we are, if we know how to use our advantage, inheritors of the wealth of all the richest times; strong in the power of the giants of all ages; placed on the summit of an edifice which thirty centuries have been employed in building.

Perhaps I shall most simply make myself intelligible by stating plainly and frankly a proposition which I wish to illustrate by various examples, as it has been exemplified in various ages and countries. The proposition is this: That every great advance in intellectual education has been the effect of some considerable scientific discovery, or group of discoveries. Every improvement of the mental discipline of those who stand in the forefront of humanity has followed some signal victory of their leaders; every addition to the means of intellectual culture has been the result of some extraordinary harvest, some more than ordinary bounty of the intellectual soil, bestowed on the preceding years.

Without further preface, let us proceed to examples. The first great attempt made for the improvement of intellectual education, so far as history tells us, was that undertaken and prosecuted with persevering vigour by Socrates and Plato. The aim of those philosophers was, I say, mainly and peculiarly, an improvement of the *intellectual education* of their countrymen. The Athenians of that time,—I mean the more eminent and affluent classes of them,—had already an education in a very considerable degree elaborate, and large and elevated in its promises. The persons by whom this education was, in its higher departments, conducted—the teachers whom Socrates and Plato perseveringly opposed—have been habitually called *the Sophists;* because, though at the time their ascendancy was immense, in the course of ages Plato's writings have superseded theirs, and he so describes them. But it has been shown recently, in the most luminous and striking manner, by one among ourselves, that the education which these teachers professed to give, and frequently gave, was precisely what we commonly mean by a *good education.* It was an education enabling a young man to write well, speak well, and act efficiently on all ordinary occasions, public and private. The moral doctrines which they taught, even according to the most unfavourable representation of them, were no worse than the moral doctrines which are most commonly taught among ourselves at the present day,—the morality founded upon *utility;* but many of them repudiated this doctrine as sordid and narrow, and professed higher principles, which they delivered in graceful literary forms, some of which are still extant in the books which we put in the hands of the young.

Such were the Sophists, against whom Socrates and Plato carried on their warfare. And why did Socrates and Plato contend against these teachers; and how was it that they contended so successfully that the sympathy of all posterity has been with them in their opposition? It was because Socrates and Plato sought for solid principles in this specious teaching, and found none. It was because, while these professors of speaking well and acting well imparted their precepts to their pupils, and exemplified them by their practice, they could not bear the keen cross-questioning of Socrates, when he tried to make them tell what it was *to speak* WELL and *to act* WELL; they could not tell Plato what was that "First Good, First Perfect, and First Fair," from which everything else derived goodness, beauty, and perfection. Socrates and Plato were not content with illustrations, they asked for principles; they were not content with rhetoric, they wanted demonstration; it was not enough for them that these men taught the young Athenian to *persuade* others, they wanted to have him *know*, and to know *what* he *knew*. These were the demands, as many of you will recollect, that recur again and again in the Platonic Dialogues. This is the tendency of all the trains of irresistible logic which are put in the mouth of Plato's imaginary Socrates. *What* do we know? *How* do we know it? *By* what *reasoning? From* what *principles?* These questions are perpetually asked. They are never completely answered. The respondent always breaks down at some point or other; and then Socrates says, with his calm irony, "How disappointing! How vexatious! We are where we were! We must begin again. We have not yet found what we were seeking. We have not yet got hold of the real and essential truth."

And what was it that had put Socrates and Plato upon this eager and obstinate search of a real and essential truth? How was it they could not be satisfied without it? Why might not that which had been taught by the wise and eloquent men of previous generations suffice for *their* generation? Why must their inquiries go further than the inquiries of their ancestors had done? This real and essential truth which they sought, what had put the notion of it into their heads? What had made them think that such a thing could be found? Had they

seen any example of such truth; had they seen any specimen of this treasure which they sought for with so vehement and persevering a quest?

Yes: for this is the point to which I wish to draw your attention; they *had* seen specimens of this treasure. They had had placed before them examples of real and certain truth; they had been admitted to contemplate clear and indisputable truths; truths which they could demonstrate to be true; truths which they could trace to principles of intuitive evidence; truths which it did not appear to be speaking too highly of if they called them necessary and eternal.

Such truths they had already seen and known; for they had known some of the truths of *geometry*. No doubt some of these truths,—the truths of geometry,—some casual and happy guesses—had been known at a much earlier period. Pythagoras had known that the squares on the two sides of a right angled triangle are equal to the square on the third. But the lore of Pythagoras, imparted in a mysterious manner to an initiated few, had long crept stealthily among the secret societies of the Italian coast, and hardly made its way, in any considerable degree, into Greece, till it was introduced by Plato and his friends. But the age of Plato was an age of great geometrical discovery in Greece. The general body of geometry, such as it exists to this day, was then constructed. Plato himself was an eminent geometer, not only by geometrical discoveries which he made, but still more by his clear and strong perception of the importance of the study. He repeatedly exhorts his fellow-countrymen to pursue this study; he promises that it shall lead them to a true view of the heavens; he discerns how this is to be done; he points out new branches of mathematical science which must be constructed for this purpose; he repeatedly refers to the Definitions, the Axioms, the Proofs of Geometrical Propositions; he writes over the gate of the gardens of Academus, where his disciples meet to listen to his teaching—Οὐδεὶς ἀγεωμέτρητος εἰσίτω. "Let no one enter who is destitute of Geometry."

And why this requirement? Why this prohibition? What was the need of Geometry for his disciples? What use was he to make of it? What inference was he to draw from it when they had it?

Precisely the inference which I have mentioned :—that there was a certain and solid truth ; a knowledge which was not mere opinion ; science which was more than seeming ; that man has powers by which such truth, such knowledge, such science, may be acquired ; that therefore it ought to be sought, not in geometry alone, but in other subjects also ; that since man can know, certainly and clearly, about straight and curved in the world of space, he ought to know,—he ought not to be content without knowing,—no less clearly and certainly, about right and wrong in the world of human action. That man has such powers was the beginning of Plato's philosophy. To use them for such purposes was the constant aim of his mental activity. The impression which had been left upon his mind by the geometrical achievements of his contemporaries, and by those which he himself began, was that the powers by which such discoveries are made are evidences of the exalted nature of the human mind ; of its vast profundity ; of its lofty destiny. He repeatedly, and with obvious gratification, refers to geometrical truths as evidences of the nature of the human mind, and even of its hope of immortality. Since the mind can thus reason *to certain truths*, it must have in it the principles *of truth ;* and whence did it derive them ? Since it can know what it has not learned from the *senses*, it must have some *other* source of knowledge ; and how much is implied in this ! Since it can conceive and bring forth eternal truths, how can it be the child of a day, a transient creature, born one moment and perishing the next ?

Perhaps it may serve to add distinctness to the account I am trying to give you of Plato's teaching if I give you, in his own way, an example of this teaching of his. It shall be very brief. In Plato's Dialogue called *Meno*, Socrates, in discourse with Meno the Thessalian, is trying to discover what Virtue is : and pressing his inquiry from point to point, and finding the truth perpetually escape him, he is led to ask at last, " What is meant by *discovering* anything ? Can we do it ? If so, how ? " And on this, with more of direct assertion than he commonly ventures upon, he declares that we *can* do it, and that he will show how we do it. He calls up a young and intelligent boy, an attendant of Meno, and he propounds to him a geometrical problem, simple, yet not quite obvious.

He draws a diagram in the sand, and asks him various questions as to the lines which serve to illustrate this problem: and the boy, though at first he says he does not know, is soon led to answer rightly to these interrogations, by his natural apprehension of the relations of space. At every step, Socrates says, "You see I tell him nothing. He goes on towards the truth, but I do not teach him. He finds it in his own mind. He does not learn from another, he recollects what he has already known. His knowledge is recollection. His science is reminiscence." *

This doctrine—that knowledge is recollection, that science is reminiscence—is the main result deduced in the *Meno* from this geometrical investigation. In that Dialogue, as I have said, the doctrine is applied to illustrate the nature of the discovery of truth in general. In the *Phedo*—that Dialogue which has so deeply moved thoughtful men in every age, in which Socrates, standing before the gates of death, reasons with his weeping friends as to what he shall find beyond them—this same doctrine is employed to warm their hopes and elevate their thoughts. Since, it is argued, the soul thus contains in itself the principles of eternal truth, it must be itself eternal. But it is not with this purpose that I here refer to the use thus made of geometrical reasoning. My object is to establish this view:—that the great step in pure scientific discovery made by the Greeks of Plato's time,—the construction of a connected and comprehensive body of geometrical truth,—led to the conviction that geometry was an immensely valuable element in intellectual education. The apprehensions of such truths threw a new light upon the nature of all truth, and the means of attaining to it. It was seen that, thenceforth, they who were altogether ignorant of geometry were destitute of the best means then known of showing them what is the genuine aspect of essential truth,—what is the nature of the intellectual vision by which it is seen,—what is the consciousness of intuitive power on which its foundations rest. And thus, in virtue of the geometrical discoveries of the Platonic epoch, geometry became a part of the discipline of the Platonic school;—became the starting-point of the Platonic reformation of the intellectual

* This portion of Plato's Dialogue, the *Meno*, was given briefly in the Lecture, a diagram being exhibited. See Note, p. 37.

education of Athens;—became an element of a liberal education. And not only became so then, but has continued so to this day: so that among ourselves, and in every other country of high cultivation, no education is held to be raised on good foundations which does not include geometry,—*elementary* geometry, at least,—among its component portions. And thus, in our Education, as in our Science, the completest form, in the latest time, includes and assumes the earliest steps of real progress: and this is so, in the one case as in the other, because the one must always depend on the other; because the progress of Education is affected, at every great and principal step, by the progress of Science.

You will not be surprised to be thus told that our modern education has derived something from the ancient Greek education, because you know that our modern science has derived much from the ancient Greek science. You know that our science, in the ordinary sense of the term, has derived little from the ancient Romans;—little, that is, which is original; and therefore you will not be surprised if our education has derived little from the Roman education. If the fact were so, it would still be a negative illustration of the doctrine which I am trying to elucidate;—the dependence of the progress of education on the progress of science. But if we take the term *science* in a somewhat wider acceptation, we shall derive from the Roman history, not a *negative*, but a *positive* exemplification of our proposition. For in that wider sense there *is* a science of which Rome was the mother, as Greece was of geometry and mathematics. The term *Science* may be extended so widely as to allow us to speak of the Science of Law—meaning the doctrine of Rights and Obligations, in its most definite and yet most comprehensive form;—in short, the Science of Jurisprudence. In this Science the Romans were really great discoverers: or rather, it was they who made the subject a Science—who gave it the precision of a Science, the generality of a science, the method of a Science. And how effectually they did this we may judge from the fact that the jurisprudence of Rome is still the basis, the model, the guide, the core of the jurisprudence of every civilized country;—of our own, less than most, but still, in no small degree, of our own. The imitators and pupils of the Greeks in every other department of human speculation,

in jurisprudence the Romans felt themselves their masters. Cicero says, proudly, but not too proudly, that a single page of a Roman jurist contained more solid and exact matter than a whole library of Greek philosophers. The labours of jurists deserving this character, which thus began before Cicero, continued through the empire, to its fall;—continued even beyond its fall. As Horace tells us that captive Greece captived the conqueror and taught him arts; so Rome subdued, subdued the victor hordes, and taught them law. The laws of Rome gave method to the codes of the northern nations, and are the origin of much that is most scientific in the more recent systems of legislation. That general law is a science we owe to the Romans; and we in England may be reminded of this by our inability to translate the Roman word by which this science is described: for though the term *jus* is the root of *jurist*, and *jurisprudence*, and the like, it is, as yet, hardly naturalized in its technical sense, as designating the general Doctrine of Rights and Obligations: nor have we any word which has that meaning, as *Droit* has in French, and *Recht* in German.

Here is a great science, then, of which the discoverers were the Romans: can we trace, as according to our view we ought to be able to trace, any corresponding great step in intellectual discipline? Was *jus* a prominent part of Roman education? Is Roman jurisprudence a prominent part in the liberal education in modern times? To both these questions we must answer most emphatically, *Yes*. The law of Rome was the main part of the education of the Roman youth. Cicero reminds his brother Quintius that they had learnt the old laws and the formulæ of legal proceedings by heart, as a sort of domestic catechism or nursery rhyme. Every Roman of eminence spent the early part of his morning in giving legal opinions to his clients:—not like our Justices of the Peace, when appealed to as a magistrate, but as an adviser and protector: and every young member of the aristocracy had to fit himself for this office. Every young Roman of condition was a Roman jurist. And the study of the law, thus made a leading branch of a liberal education, continued so through the Middle Ages—continues so still. It occupied the great Italian universities—Bologna, Pisa, Padua, and the like—in the darkest parts of the

Dark Ages. It occupies most of the universities of Europe to this day. The Roman law is still the main element of the liberal education of Italy, of Germany, of Greece, and, in some degree, even of France and Spain. In Germany its prevalence has been such that in recent times all the great moral controversies have been debated in the most strenuous and searching manner *in terms* of the *Civil Law*, as the Roman law is still called all over Europe. And we shall hardly doubt, if we look into the matter, that these legal studies have given to the well-educated men of those countries a precision of thought and an exactness of logic on moral subjects which, without such a study, would not have been likely to prevail. To define a Right or Obligation, to use proper terms in framing a law, in delivering a judicial sentence, in giving a legal opinion, is precisely the merit of an accomplished jurist; as is emphatically asserted by Cicero. And even our own law, fragmentary and unscientific as it is, is not without a value of the same kind, as an instrument of a liberal education. It may be a means of giving exactness to the thoughts, method and clearness to the reasoning, precision to the expressions of men, on the general interests of man and of society; and is *so* recommended, and often so employed, by those who are preparing for active life. Of the moral sciences, without some study of which no education can be complete, the science of jurisprudence is most truly a science, and most effectually a means of intellectual discipline. And, as you see, the use of such discipline in education dates from the period of that great advance in speculation on moral subjects and social relations by which jurisprudence became a science.

And thus two of the great elements of a thorough intellectual culture, Mathematics and Jurisprudence, are an inheritance which we derive from ages long gone by; from two great nations; from *the* two great nations of antiquity. They are the results of ancient triumphs of man's spirit over the confusion and obscurity of the aspects of the external world; and even over the waywardness and unregulated impulses of his own nature, and the entanglements and conflicts of human society. And being true sciences they were well fitted to become, as they became, and were fitted to continue, as they have hitherto continued, to be main elements in that discipline by which man is to raise himself above himself; is to raise,—since that is

especially what we have now to consider,—his intellect into a habitual condition, superior to the rudeness, dimness, confusion, laxity, insecurity, to which the *undisciplined* impulses of human thought in all ages and nations commonly lead.

And before we proceed any further, let us consider, for an instant, that such an education, consisting of the elements which I have mentioned, might be, and would be, in well-conducted cases, an education of no common excellence, even according to our present standard of a good intellectual education. A mind well disciplined in elementary geometry and in general jurisprudence would be as well prepared as mere discipline can make a mind for most trains of human speculation and reasoning. The mathematical portion of such an education would give clear habits of logical deduction, and a perception of the delight of demonstration; while the *moral* portion of the education, as we may call jurisprudence, would guard the mind from the defect, sometimes ascribed to mere mathematicians, of seeing none but mathematical proofs, and applying to all cases mathematical processes. A young man well imbued with these, the leading elements of Athenian and Roman culture, would, we need not fear to say, be superior in intellectual discipline to three-fourths of the young men of our own day, on whom all the ordinary appliances of what is called *a good education* have been bestowed. Geometer and jurist, the pupil formed by this culture of the old world, might make no bad figure among the men of letters or of science, the lawyers and the politicians of our own times.

But there is another remark which I must make, tending to show the *defect* of this education of antiquity, as compared with the intellectual education of our own times; or rather, as compared with what the education of our own times ought to be. The subjects which I have mentioned, geometry and jurisprudence, are both *deductive* sciences—sciences in which, from certain first principles, by chains of proof, conclusions are deduced which constitute the doctrines of the science. In the one case, geometry, these first principles are given by intuition; in the other, jurisprudence, they are either rules instituted by authority and consent, or general principles of human nature and human society obtained from experience interpreted by ou own human consciousness. We deduce properties of diagram

from geometrical axioms; we deduce decisions of cases from legal maxims. Jurisprudence, no less than geometry, is a deductive science; and has been compared with geometry, by its admirers, for the exactness of its deductive processes. They have said (Leibnitz and others) that jural demonstrations are as fine examples of logic as mathematical; and that pure reason alone determines every expression of a good jurist, no less than a good mathematician; so that there is no room for that play of individual character which shows itself in the difference of style of different authors. But however perfectly the habits of *deduction* may be taught by these studies, such teaching cannot, according to the enlarged views of modern times, compose a complete intellectual culture. Induction, rather than deduction, is the source of the great scientific truths which form the glory, and fasten on them the admiration of modern times; and a modern education cannot be regarded as giving to the intellect that culture which the fullness of time, and the treasures of knowledge now accumulated, render suitable and necessary, except it convey to the mind an adequate appreciation of and familiarity with the *inductive* process by which those treasures of knowledge have been obtained. As the best sciences which the ancient world framed supplied the best elements of intellectual education up to modern times, so the grand step by which, in modern times, science has sprung up into a magnitude and majesty far superior to her ancient dimensions should exercise its influence upon modern education, and contribute its proper result to modern intellectual culture.

Who is to be taken as the representative of the great epoch of the progress of science in modern times; that is, beginning from the sixteenth century? In different ways, Galileo, Descartes, Bacon, Newton, may seem best suited to occupy that position. But Galileo's immediate influence was limited, both as to subjects and as to the number of admirers. It was when Descartes summed up into a *system* the discoveries of Galileo and his disciples, and added to them inventions of his own, some true, many captivating, that the new physical philosophy acquired a large and vigorous hold upon Europe north of the Alps. In France especially, always eager in its admiration of intellectual greatness, Descartes was unhesitatingly regarded as the great man who brought in a new and more enlightened

age of philosophy. Indeed, for a large portion of philosophy, he is still so regarded by French philosophers; and though his influence in metaphysics is to be distinguished from his authority in physics, still the ascendancy of his more abstract and general philosophical opinions was closely connected with his recognized eminence as a physical philosopher, and with the admiration which his system of the universe obtained. The Cartesian philosophy was the proclaimed and acknowledged antagonist of the Aristotelian philosophy; it was the new truth of which the standard was raised against the old falsehood. Any one acquainted with the French literature of the seventeenth century will recollect innumerable illustrations of this view of the matter. You remember, perhaps (as an example), the noted passage in Fontenelle's lively dialogues on *The Plurality of Worlds*. There, the sages of antiquity, the Pythagorases, Platos, Aristotles, are represented as looking at the spectacle of the universe like so many spectators in the pit of the Opera House looking at the ballet. The subject of the ballet is supposed to be Phaëton carried away by the winds: and to represent this, the dancer who enacts the part of Phaëton is made to fly away through the upper part of the scene, to the great admiration of the gazers. The more speculative of these attempt to explain this extraordinary movement of Phaëton. One says, "Phaëton has an *occult quality*, which carries him away." This is the Aristotelian. Another says, "Phaëton is composed of certain *numbers* which make him move upwards." This is the Pythagorean. Another says, "Phaëton has a longing for the top of the theatre. He is not easy till he gets there." This is the philosophy which explains the universe by Love and Hate. Another says, "Phaëton has not naturally a tendency to fly; but he prefers flying to leaving the top of the scene empty." This is the doctrine of the *fuga vacui*, nature's horror of a vacuum. And after all this, says the speaker, comes Descartes and some other moderns; and they say, Phaëton goes up, because he is drawn by certain cords, and a weight, heavier than he is, goes down behind the scenes. And in truth the physical philosophy of Descartes did contain the greater part of the true explanation of the phenomena of the universe which was known up to this time. It contained the principles of Mechanics, with few errors: the principles of Optics, and the

beautiful explanation of the rainbow, in the discovery of which Descartes had so large a share ; and a true system of Astronomy, so far as the mere motions are concerned. And Descrates's peculiar invention, the hypothesis of *tourbillons*—vortices or whirlpools of celestial fluid, by which these motions are produced—though false, was not only separable from the other parts of the system, but was capable, by modifications, of expressing many mechanical truths, as the Bernoullis and other mathematicians who retained it for a century often showed. In England, as in France, the Cartesian philosophy meant the Mechanical Philosophy as opposed to the philosophy of sympathies and antipathies, occult qualities, arbitrary notions of Nature, and the like. The Cartesian philosophy, in this sense, was introduced into England : but I doubt whether the doctrine of vortices was ever accepted here to any considerable extent. It has been made, I may be allowed to say ignorantly and absurdly made, an accusation against the University of Cambridge that the Cartesian system found acceptance there. Such an event showed a promptitude in accepting new scientific views which has repeatedly been exemplified there. But I much doubt whether the Cartesian system was *ever* presented to Cambridge students without a refutation of the vortices being put in the notes on the same page. Assuredly it was not taught for more than a few years in any other form : but, I believe, not at all. And in like manner, in other places, the new mechanical philosophy, Cartesian in France, Newtonian in England, rapidly superseded the verbal dogmatism of the Middle Ages.

And with this triumph of the new opinions, as a revolution in science, came the introduction of the new doctrines as a revolution, or extension, in education. The Cartesian philosophy,—instantly in England transformed into the Newtonian philosophy on the publication of Newton's mighty discoveries, —was eagerly received, from its very first appearance, and incorporated with the elements of a liberal education, both in Newton's own university and elsewhere. And not only were the new theories of the solar system rapidly diffused, by means of lectures, books, and in other ways ; but the principles by which such theories are collected from observation,—the principles of that induction, on which this great fabric of science rests,—became objects of attention, respect, and praise. Bacon,

with his majestic voice,—the trumpeter who stirred up the battle, as he himself calls himself,—had already prepared men's minds for this feeling of respect and admiration for inductive discovery, even while the movement was only beginning: and in this country at least, many persons, Gilbert, Cowley, and others, had re-echoed the sentiment which he expressed. He had declared that knowledge, far more ample and complete than had yet been obtained by man, was to be gained by the use of new methods of investigation: and the succeeding time, having produced noble examples of such knowledge, had made men see that they had entered upon a new epoch of science. And it was natural and desirable that in this, as in other cases, the possession of a body of new truths, and the admiration of the method by which these had been acquired, should operate upon the culture of the intellect among those who sought the best means of such culture—should introduce new elements into liberal education—should make it a part of the mental discipline of the best taught classes, that they should learn to feel the force and see the beauty of *inductive* reasoning; as the older elements of a liberal education, mathematics and jurisprudence, had been employed, among other uses, to make men feel the force, and see the beauty, of deductive reasoning.

And thus we are naturally led to ask, Has this been done? Has education in its most advanced form been thus extended? Is there, in the habitual culture of the intellect, in the best system of education, this cultivation of the habit, or at least of the appreciation, of inductive teaching in science? How is such culture to be effected? How are we to judge whether it has been effected?

These are very large questions, and yet the time admonishes me, if nothing else did, that I must be very brief in any answers that I may give to them. I must content myself with a hint or two bearing upon the subject. And first, of the mode in which this culture of the inductive habit of mind, or at least appreciation of the method and its results, is to be promoted; if I might presume to give an opinion, I should say that one obvious mode of effecting this discipline of the mind in induction is the exact and solid study of some portion of inductive knowledge. I do not mean the mechanical sciences alone, Physical Astronomy and the like; though these undoubtedly have a

prerogative value as the instruments of such a culture; but the like effect will be promoted by the exact and solid study of any portion of the circle of natural sciences—Botany, Comparative Anatomy, Geology, Chemistry, for instance. But I say the *exact* and *solid* knowledge; not a mere verbal knowledge, but a knowledge which is real in its character, though it may be elementary and limited in its extent. The knowledge of which I speak must be a knowledge of things, and not merely of names of things; an acquaintance with the operations and productions of nature, as they appear to the eye, not merely an acquaintance with what has been said about them; a knowledge of the laws of nature, seen in special experiments and observations, before they are conceived in general terms; a knowledge of the types of natural forms, gathered from individual cases already made familiar. By such study of one or more departments of inductive knowledge the mind may escape from the thraldom and illusion which reigns in the world of mere words.

But there is another study which I may venture to mention, of a more general and literary kind, also eminently fitted to promote an appreciation of the nature and value of the inductive treatment of nature. I mean the History of the Natural Sciences; for in such history we see how, in the study of every portion of the universe, the human mind has ascended from particular facts to general laws; and yet in every different class of phenomena by processes very *different*, at first sight at least. And I mention this study of the history of science, and especially recommend it, the rather because it supplies, as I conceive, a remedy for some of the evils which, along with great advantages, may result from *another* study which has long been, and at present is, extensively employed as an element of a liberal education—I mean the study of *Logic*. The study of Logic is of great value as fixing attention upon the conditions of deductive proof, and giving systematic and technical views of the forms which such proof may assume. But by doing this for all subjects alike it produces the impression that there is a close likeness in the process of investigation of truth in different subjects;—closer than there really is. The examples of reasoning given in books of Logic are generally so trifling as to seem a mockery of truth-seeking, and so monotonous as to seem idle

variations of the same theme. But in the History of Science we see the infinite variety of nature; of mental no less than bodily nature; of the intellectual as well as of the sensible world. The modes of generalization of particulars,—of ascent from the most actual things to the most abstract ideas,—how different are they in botany, in chemistry, in geology, in physiology!—yet all most true and real; all most certain and solid; all of them genuine and indisputable lines of union and connexion, by which the mind of man and the facts of the universe are bound together; by which the universe becomes a sphere with intellect for its centre; by which intellect becomes in no small degree able to bend to its purposes the powers of the universe.

The history of science, showing us how this takes place in various forms,—ever and ever new, when they seem to have been exhausted,—*may* do, and carefully studied *must* do, much to promote that due apprehension and appreciation of inductive discovery: and inductive discovery, now that the process has been going on with immense vigour in the nations of Europe for the last three hundred years, ought, we venture to say, to form a distinct and prominent part of the intellectual education of the youth of those nations. And having said this, I have given you the ultimate result of the reflections which have occurred to me on this subject of intellectual education on which I have ventured to address you. And here, therefore, I might conclude. But if it did not weary you, I should wish to make a remark on the other of the two questions which I asked a little while ago. I then asked, How is such a culture to be effected? and also, How are we to judge whether it has been effected?

With regard to the latter question, the remark which I have to make is briefly this: In the inductive sciences, every step of generalization is usually marked by some *word*, which, adopted to mark that step, acquires thenceforth a fixed and definite meaning; and is always to be used in the sense so given it, not in any other way in which other resemblances or incidents may suggest. And the definition of *technical words* in inductive science is contained in the history of the science; is given by the course of previous research and discovery. "The history of science is our dictionary; the steps of scientific induction are

our definitions." Now this being so, we may remark that when we hear a man, in the course of an argument, asking for Definitions, as something by which error is to be avoided and truth learned, such a demand is evidence that his intellectual training has been deductive, not inductive—logical, not scientific. In geometry, and in other demonstrative sciences, Definitions are the beginning of the science—the fountains of truth. But it is not so in the inductive sciences. In such sciences a Definition and a Proposition commonly enter side by side—the definition giving exactness to the proposition; the proposition giving reality to the definition.

But further:—as technical terms, appropriate to a precise and steady sense, mark every step of inductive ascent in science, the exact and correct use of the technical terms of science is evidence of good inductive culture of the mind; and a vague and improper use of such terms is evidence of the absence of such culture. When we hear men speak, as we often do, of *impetus* and *momentum*, of *gravity* and *inertia*, of *centripetal* and *centrifugal force*, and the like, using the terms mostly by guess,—and assuming oppositions and relations among them which do not exist;—as, for instance, when they oppose the centrifugal and centripetal force, as if they were *forces* in the same sense;—we cannot help saying that such persons, however ingenious and quick they may be in picking a possible meaning out of current words by means of their etymology or any other casual light, have not the habit of gathering the meaning of scientific words from the only true light, the light of induction.

And this remark may not be without a special use if we recollect that there are at present a number of scientific words current among us which are applied with the most fantastical and wanton vagueness of meaning, or of no meaning. At all periods of science, probably, scientific terms are liable to this abuse, after scientific discoveries have brought them into notoriety, and before the diffusion of science has made their true meaning to be generally apprehended. The names, indeed, of *attraction*, *gravitation*, and the like have probably now risen, in a great degree, out of this sphere of confusion and obscurity, in which any word may mean anything. But there are words —belonging to sciences which have more recently reached dignity,—which words every one pursuing fancies which are

utterly out of the sphere of science seems to think he may use just as he pleases. *Magnetism* and *Electricity*, and the terms which belong to these sciences, are especially taken possession of for such purposes, and applied in cases in which we know that the sciences from which the names are "*conveyed*" have not the smallest application. Is Animal Magnetism anything? Let those answer who think they can: but *we* know that it is not *Magnetism*. When I say *we*, I mean those who are in the habit of seeing in this place the admirable exhibitions of what Magnetism is, with which you have long been familiar. And assuredly, on the same ground, I may say that you have been shown, and know, what Electricity is, and what it can do; and what it cannot do, and what is not Electricity. And having had the opportunity of seeing this, you, at least, have so much of the culture of the intellect which inductive science supplies as not to suppose that your words would have any meaning if you were to say of any freak of fancy or will, shown in bodily motion or muscular action, that it is *a kind of Electricity*.

NOTE TO p. 25

EXTRACT FROM THE "MENO" OF PLATO

S. Tell me, boy, do you know that this figure is a square?—*B.* Yes, I know.

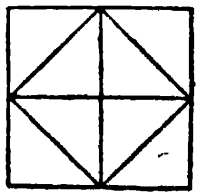
S. Because all these four lines are equal (its sides)?—*B.* Yes.

S. And also these other two lines are equal, which are drawn across the middle? (the diagonals)—*B.* Yes.

S. May there be a square greater or less than this?—*B.* Yes.

S. May there be a square twice as great as this?—*B.* Yes.

S. How long must one side be, that the square may be twice as great?—*B.* Twice as long as the side of the first square.



You see, Socrates says, I tell him nothing, I only ask him questions. And now he thinks he has answered right. But I must revive his recollection, that he may see his error.—So you say that the square on a double line will be double of the first square? You know I mean a square, not a figure that is long one way and narrow the other; but as broad as it is long, like this square, only twice as large. Now let us fit to one end of the first square a second square which is equal to it. And let us fit two other squares of the same size to the sides of those two squares. Then we have a new square, have we not?—*B.* Yes.

S. And how many times is it greater than the first square?—*B.* Four times greater.

S. Not twice as great, which you said?—*B.* No: four times.

S. Well: but how long must the line be that the square upon it may be twice as great as the first square?—*B.* I do not know.

Now, says Socrates, mark, that out of this not knowing, he will come to know, by seeking with me, just as he comes to know when I question him without my telling him anything. You will see that I do not give him my opinion, I only get at his.—If we draw a line across this first square, from corner to corner (the diagonal), it cuts it into two equal parts, does it not ?—*B.* Yes.

S. And if in this square, which is made up of the four squares, we draw the four diagonals, so as to cut off the four outside corners, each of these diagonals will cut one of the squares into two halves ?—*B.* Yes.

S. And these four diagonals will be equal, and will make a new square ?—*B.* Yes.

S. And this square is made up of the four inside halves of the four squares, is it not ? —*B.* It is.

S. But the first square is made up of two such halves, is it not ?—*B.* Yes.

S. And how much is four times greater than twice ?—*B.* The double of it.

S. Then how many times is the new square greater than the first square ?—*B.* It is the double of it.

S. Then you have got a square which is the double of the original square ?—*B.* Yes.

S. Namely, the square upon the diagonal of the original square?—*B.* Yes.

You see, Socrates says, he was really possessed of all his knowledge before. Those who do not know have still in their minds a latent knowledge.

OBSERVATIONS ON MENTAL EDUCATION

A LECTURE DELIVERED AT THE ROYAL INSTITUTION OF GREAT BRITAIN, BEFORE H.R.H. PRINCE ALBERT

By PROFESSOR FARADAY, LL.D., F.R.S.

I TAKE courage, Sir, from your presence here this day, to speak boldly that which is upon my mind. I feared that it might be unpleasant to some of my audience, but as I know that your Royal Highness is a champion for and desires the truth, I will believe that all here are united in the same cause, and therefore will give utterance, without hesitation, to what I have to say regarding the present condition of Mental Education.

If the term education may be understood in so large a sense as to include all that belongs to the improvement of the mind, either by the acquisition of the knowledge of others, or by increase of it through its own exertions, then I may hope to be justified for bringing forward a few desultory observations respecting the exercise of the mental powers in a particular direction, which otherwise might seem out of place. The points I have in view are general, but they are manifest in a striking manner, among the physical matters which have occupied my life; and as the latter afford a field for exercise in which cogitations and conclusions can be subjected to the rigid tests of fact and experiment—as all classes employ themselves more or less in the consideration of physical matters, and may do so with great advantage, if inclined in the least degree to profit by educational practices, so I hope that what I may say will find its application in every condition of life.

Before entering upon the subject, I must take one distinction which, however it may appear to others, is to me of the utmost importance. High as man is placed above the creatures around him, there is a higher and far more exalted position

within his view; and the ways are infinite in which he occupies his thoughts about the fears, or hopes, or expectations of a future life. I believe that the truth of that future cannot be brought to his knowledge by any exertion of his mental powers, however exalted they may be; that it is made known to him by other teaching than his own, and is received through simple belief of the testimony given. Let no one suppose for a moment that the self-education I am about to commend in respect of the things of this life extends to any considerations of the hope set before us, as if man by reasoning could find out God. It would be improper here to enter upon this subject further than to claim an absolute distinction between religious and ordinary belief. I shall be reproached with the weakness of refusing to apply those mental operations which I think good in respect of high things to the very highest. I am content to bear the reproach. Yet, even in earthly matters, I believe that the invisible things of Him from the creation of the world are clearly seen, being understood by the things that are made, even His eternal power and Godhead; and I have never seen anything incompatible between those things of man which can be known by the spirit of man which is within him, and those higher things concerning his future which he cannot know by that spirit.

Claiming, then, the use of the ordinary faculties of the mind in ordinary things, let me next endeavour to point out what appears to me to be a great deficiency in the exercise of the mental powers in every direction; three words will express this great want, *deficiency of judgment*. I do not wish to make any startling assertion, but I know that in physical matters multitudes are ready to draw conclusions who have little or no power of judgment in the cases; that the same is true of other departments of knowledge; and that, generally, mankind is willing to leave the faculties which relate to judgment almost entirely uneducated, and their decisions at the mercy of ignorance, prepossessions, the passions, or even accident.

Do not suppose, because I stand here and speak thus, making no exceptions, that I except myself. I have learned to know that I fall infinitely short of that efficacious exercise of the judgment which may be attained. There are exceptions to my general conclusion, numerous and high; but if we desire

to know how far education is required, we do not consider the few who need it not, but the many who have it not; and in respect of judgment, the number of the latter is almost infinite. I am moreover persuaded that the clear and powerful minds which have realized in some degree the intellectual preparation I am about to refer to, will admit its importance, and indeed its necessity; and that they will not except themselves, nor think that I have made my statement too extensive.

As I believe that a very large proportion of the errors we make in judgment is a simple and direct result of our perfectly unconscious state, and think that a demonstration of the liabilities we are subject to would aid greatly in providing a remedy, I will proceed first to a few illustrations of a physical nature. Nothing can better supply them than the intimations we derive from our senses; to them we trust directly, by them we become acquainted with external things, and gain the power of increasing and varying facts upon which we entirely depend. Our sense perceptions are wonderful. Even in the observant but unreflective infant they soon produce a result which looks like intuition, because of its perfection. Coming to the mind as so many data, they are stored up, and without our being conscious of it are ever after used in like circumstances in forming our judgment; and it is not wonderful that man is accustomed to trust them without examination. Nevertheless, the result is the effect of education: the mind has to be instructed with regard to the senses and their intimations through every step of life; and where the instruction is imperfect, it is astonishing how soon and how much their evidence fails us. Yet, in the latter years of life, we do not consider this matter, but, having obtained the ordinary teaching sufficient for ordinary purposes, we venture to judge of things which are extraordinary for the time, and almost always with the more assurance as our powers of observation are less educated. Consider the following case of a physical impression, derived from the sense of touch, which can be examined and verified at pleasure: If the hands be brought towards each other so that the tips of the corresponding fingers touch, the end of any finger may be considered as an object to be felt by the opposed finger, thus the two middle fingers may for the present be so viewed. If the attention be directed to them,

no difficulty will be experienced in moving each lightly in a circle round the tip of the other, so that they shall each feel the opposite, and the motion may be either in one direction or the other—looking at the fingers, or with eyes employed elsewhere—or with the remaining fingers touching quiescently, or moving in a like direction; all is easy, because each finger is employed in the ordinary or educated manner whilst obeying the will, and whilst communicating through the sentient organ with the brain. But turn the hands half-way round, so that their backs shall be towards each other, and then, crossing them at the wrists, again bring the like fingers into contact at the tips. If it be now desired to move the extremities of the middle fingers round each other, or to follow the contour of one finger by the tip of the opposed one, all sorts of confusion in the motion will ensue; and as the finger of one hand tries, under the instruction of the will, to move in one course, the touched finger will convey an intimation that it is moving in another. If all the fingers move at once, all will be in confusion, the ease and simplicity of the first case having entirely disappeared. If, after some considerable trial, familiarity with the new circumstances have removed part of the uncertainty, then, crossing the hands at the opposite sides of the wrists will renew it. These contrary results are dependent, not on any change in the nature of the sentient indication, or of the surfaces or substances which the sense has to deal with, but upon the trifling circumstance of a little variation from the direction in which the sentient organs of these parts are usually exerted, and they show to what an extraordinary extent our interpretations of the sense impressions depend upon the experience, i.e. the education which they have previously received, and their great inability to aid us at once in circumstances which are entirely new.

At other times they fail us because we cannot keep a true remembrance of former impressions. Thus, on the evening of the eleventh of March last, I and many others were persuaded that at one period the moon had a real green colour, and though I knew that the prevailing red tints of the general sky were competent to produce an effect of such a kind, yet there was so little of that in the neighbourhood of the planet, that I was doubtful whether the green tint was not produced on

the moon by some aerial medium spread before it, until, by holding up white cards in a proper position, and comparing them with our satellite, I had determined experimentally that the effect was only one of contrast. In the midst of the surrounding tints, my memory could not recall the true sentient impression which the white of the moon most surely had before made upon the eye.

At other times the failure is because one impression is overpowered by another; for as the morning star disappears when the sun is risen, though still above the horizon and shining brightly as ever, so do stronger phenomena obscure weaker, even when both are of the same kind; till an uninstructed person is apt to pass the weaker unobserved, and even deny their existence.

So, error results occasionally from believing our senses: it ought to be considered, rather, as an *error of the judgment* than of the sense, for the latter has performed its duty; the indication is always correct, and in harmony with the great truth of nature. Where, then, is the mistake?—almost entirely with our judgment. We have not had that sufficient instruction by the senses which would justify our making a conclusion; we have to contrive extra and special means, by which their first impressions shall be corrected, or rather enlarged; and it is because our procedure was hasty, our data too few, and our judgment untaught, that we fell into mistake; not because the data were wrong. How frequently may each one of us perceive, in our neighbours, at least, that a result like this derived from the observation of physical things, happens in the ordinary affairs of common life.

When I become convicted of such haste, which is not infrequently the case, I look back upon the error as one of "presumptuous judgment." Under that form it is easily presentable to the mind, and has a useful corrective action. I do not think the expression too strong; for if we are led, either by simplicity or vanity, to give an opinion upon matters respecting which we are not instructed, either by the knowledge of others, or our own intimate observation; if we are induced to ascribe an effect to one force, or deny its relation to another, knowing little or nothing of the laws of the forces, or the necessary conditions of the effect to be considered; surely our judgment must be qualified as "presumptuous."

There are multitudes who think themselves competent to decide, after the most cursory observation, upon the cause of this or that event (and they may be really very acute and correct in things familiar to them) :—a not unusual phrase with them is, that " it stands to reason," that the effect they expect should result from the cause they assign to it, and yet it is *very difficult*, in numerous cases that appear plain, to show this reason, or to deduce the true and only rational relation of cause and effect. In matters connected with natural philosophy, we have wonderful aid in the progress and assurance in the character, of our final judgment, afforded us by the facts which supply our data, and the experience which multiplies their number and varies their testimony. A fundamental fact, like an elementary principle, never fails us, its evidence is always true ; but, on the other hand, we frequently have to ask what is the fact ?—often fail in distinguishing it,—often fail in the very statement of it,—and mostly overpass or come short of its true recognition.

If we are subject to mistake in the interpretation of our mere sense impressions, we are much more liable to error when we proceed to deduce from these impressions (as supplied to us by our ordinary experience), the relation of cause and effect ; and the accuracy of our judgment, consequently, is more endangered. Then our dependence should be upon carefully observed facts, and the laws of nature ; and I shall proceed to a further illustration of the mental deficiency I speak of, by a brief reference to one of these.

The *laws of nature*, as we understand them, are the foundation of our knowledge in natural things. So much as we know of them has been developed by the successive energies of the highest intellects, exerted through many ages. After a most rigid and scrutinizing examination upon principle and trial, a definite expression has been given to them ; they have become, as it were, our belief or trust. From day to day we still examine and test our expressions of them. We have no interest in their retention if erroneous ; on the contrary, the greatest discovery a man could make would be to prove that one of these accepted laws was erroneous, and his greatest honour would be the discovery. Neither would there be any desire to retain the former expression :—for we know that the new or the amended

law would be far more productive in results, would greatly increase our intellectual acquisitions, and would prove an abundant source of fresh delight to the mind.

These laws are numerous, and are more or less comprehensive. They are also precise; for a law may present an apparent exception, and yet not be less a law to us, when the exception is included in the expression. Thus, that elevation of temperature expands all bodies is a well-defined law, though there be an exception in water for a limited temperature; because we are careful, whilst stating the law, to state the exception and its limits. Pre-eminent among these laws, because of its simplicity, its universality, and its undeviating truth, stands that enunciated by Newton (commonly called the *law of gravitation*), that matter attracts matter with a force inversely as the square of the distance. Newton showed that, by this law, the general condition of things on the surface of the earth is governed; and the globe itself, with all upon it, kept together as a whole. He demonstrated that the motions of the planets round the sun, and of the satellites about the planets, were subject to it. During and since his time, certain variations in the movements of the planets, which were called irregularities, and might, for aught that was then known, be due to some cause other than the attraction of gravitation, were found to be its necessary consequences (see Note A). By the close and scrutinizing attention of minds the most persevering and careful, it was ascertained that even the distant stars were subject to this law; and, at last, to place as it were the seal of assurance to its never-failing truth, it became, in the minds of Leverrier and Adams (1845), the foreteller and the discoverer of an orb rolling in the depths of space, so large as to equal nearly sixty earths, yet so far away as to be invisible to the unassisted eye. What truth, beneath that of revelation, can have an assurance stronger than this!

Yet this law is often cast aside as of no value or authority, because of the unconscious ignorance amidst which we dwell. You hear at the present day, that some persons can place their fingers on a table, and then elevating their hands, the table will rise up and follow them; that the piece of furniture, though heavy, will ascend, and that their hands bear no weight, or are not drawn down to the wood; you do not hear of this as a

conjuring manœuvre, to be shown for your amusement, but are expected seriously to believe it; and are told that it is an important fact, a great discovery amongst the truths of nature. Your neighbour, a well-meaning, conscientious person, believes it; and the assertion finds acceptance in every rank of society, and amongst classes which are esteemed to be educated. Now what can this imply but that society, speaking generally, is not only ignorant as respects education of the judgment, but is also ignorant of its ignorance. The parties who are thus persuaded, and those who are inclined to think and to hope that they are right, throw up Newton's law at once, and *that* in a case which of all others is fitted to be tested by it; or if the law be erroneous, to test the law. I will not say they oppose the law, though I *have* heard the supposed fact quoted triumphantly against it; but as far as my observation has gone, they will not apply it. The law affords the simplest means of testing the fact, and if there be, indeed, anything in the latter new to our knowledge (and who shall say that new matter is not presented to us daily, passing away unrecognized), it also affords the means of placing *that* before us separately in its simplicity and truth. Then why not consent to apply the knowledge we have to that which is under development? Shall we educate ourselves in what is known, and then casting away all we have acquired, turn to our ignorance for aid to guide us among the unknown? If so, instruct a man to write, but employ one who is unacquainted with letters to read that which is written; the end will be just as unsatisfactory, though not so injurious, for the book of nature, which we have to read, is written by the finger of God. Why should not one who can thus lift a table proceed to verify and simplify his fact, and bring it into relation with the law of Newton? Why should he not take the top of his table (it may be a small one), and placing it in a balance, or on a lever, proceed to ascertain how much weight he can raise by the draught of his fingers upwards; and of this weight, so ascertained, how much is unrepresented by any pull upon the fingers downward? He will then be able to investigate the further question, whether electricity, or any new force of matter, is made manifest in his operations; or whether action and reaction being unequal, he has at his command the source of a perpetual motion. Such a man, furnished

with a nicely constructed carriage on a railway, ought to travel by the mere draught of his own fingers. A far less prize than this would gain him the attention of the whole scientific and commercial world; and he may rest assured, that if he can make the most delicate balance incline or decline by attraction, though it be only with the force of an ounce, or even a grain, he will not fail to gain universal respect and most honourable reward.

When we think of the laws of nature (which by continued observation have become known to us) as the proper tests to which any new fact or our theoretical representation of it should, in the first place, be subjected, let us contemplate their assured and large character. Let us go out into the field and look at the heavens with their solar, starry, and planetary glories; the sky with its clouds; the waters descending from above or wandering at our feet; the animals, the trees, the plants; and consider the permanency of their actions and conditions under the government of these laws. The most delicate flower, the tenderest insect, continues in its species through countless years; always varying, yet ever the same (see Note B). When we think we have discovered a departure, as in the *Aphides*, *Medusæ*, *Distomæ*, &c.,* the law concerned is itself the best means of instituting an investigation, and hitherto we have always found the witness to return to its original testimony. These frail things are never-ceasing, never-changing evidence of the law's immutability (see Note C). It would be well for a man who has an anomalous case before him, to contemplate a blade of grass, and when he has considered the numerous ceaseless, yet certain, actions there located, and his inability to change the character of the least among them (see also Note C), to recur to his new subject; and, in place of accepting unwatched and unchecked results, to search for a like certainty and recurrence in the appearances and actions which belong to it.

Perhaps it may be said, the delusion of table-moving is past, and need not be recalled before an audience like the present; † —even granting this, let us endeavour to make the subject

* See Claparède's Account of Alternating Generation and the Metamorphoses of Inferior Animals.—*Bib. Univ.*, March 1854, p. 229.

† See Note, p. 67.

leave one useful result; let it serve for an example, not to pass into forgetfulness. It is so recent, and was received by the public in a manner so strange, as to justify a reference to it, in proof of the uneducated condition of the general mind. I do not object to table-moving for *itself;* for being once stated it becomes a fit though a very unpromising subject for experiment; but I am opposed to the unwillingness of its advocates to investigate; their boldness to assert; the credulity of the lookers-on; their desire that the reserved and cautious objector should be in error; and I wish, by calling attention to these things, to make the general want of mental discipline and education manifest.

Having endeavoured to point out this great deficiency in the exercise of the intellect, I will offer a few remarks upon the means of subjecting it to the improving processes of instruction. Perhaps many who watch over the interests of the community, and are anxious for its welfare, will conclude, that the development of the judgment cannot properly be included in the general idea of education; that as the education proposed must, to a very large degree, be of *self*, it is so far incommunicable; that the master and the scholar merge into one, and both disappear; that the instructor is no wiser than the one to be instructed, and thus the usual relations of the two lose their power. Still, I believe that the judgment may be educated to a very large extent, and might refer to the fine arts as giving proof in the affirmative; and though, as respects the community and its improvement in relation to common things, any useful education must be of *self*, I think that society, as a body, may act powerfully in the cause. Or it may still be objected that my experience is imperfect, is chiefly derived from exercise of the mind within the precincts of natural philosophy, and has not that generality of application which can make it of any value to society at large. I can only repeat my conviction, that society occupies itself nowadays about physical matters, and judges them as common things. Failing in relation to them, it is equally liable to carry such failures into other matters of life. The proof of deficient judgment in one department shows the habit of mind, and the general want, in relation to

others. I am persuaded that all persons may find in natural things an admirable school for self-instruction, and a field for the necessary mental exercise; that they may easily apply their habits of thought, thus formed, to a social use; and that they ought to do this, as a duty to themselves and their generation.

Let me first try to illustrate the former part of the case, and at the same time state what I think a man may and ought to do for himself.

The *self-education* to which he should be stimulated by the desire to improve his judgment, requires no blind dependence upon the dogmas of others, but is commended to him by the suggestions and dictates of his own common sense. The first part of it is founded in mental discipline: happily it requires no unpleasant avowals; appearances are preserved, and vanity remains unhurt; but it is necessary that a man *examine himself*, and *that* not carelessly. On the contrary, as he advances, he should become more and more strict, till he ultimately prove a sharper critic to himself than any one else can be; and he ought to intend this, for, so far as he consciously falls short of it, he acknowledges that others may have reason on their side when they criticize him. A first result of this habit of mind will be an internal conviction of *ignorance in many things respecting which his neighbours are taught*, and, that his opinions and conclusions on such matters ought to be advanced with reservation. A mind so disciplined will be *open to correction upon good grounds in all things*, even in those it is best acquainted with; and should familiarize itself with the idea of such being the case: for though it sees no reason to suppose itself in error, yet the possibility exists. The mind is not enfeebled by this internal admission, but strengthened; for, if it cannot distinguish proportionately between the probable right and wrong of things known imperfectly, it will tend either to be rash or to hesitate; whilst that which admits the due amount of probability is likely to be justified in the end. It is right that we should stand by and act on our principles; but not right to hold them in obstinate blindness, or retain them when proved to be erroneous. I remember the time when I believed a spark was produced between voltaic metals as they approached to contact (and the reasons why it might be possible yet remain);

but others doubted the fact and denied the proofs, and on re-examination I found reason to admit their corrections were well founded (see Note D). Years ago I believed that electrolytes could conduct electricity by a conduction proper; that has also been denied by many through long time: though I believed myself right, yet circumstances have induced me to pay that respect to criticism as to reinvestigate the subject, and I have the pleasure of thinking that nature confirms my original conclusions (see Note E). So though evidence may appear to preponderate extremely in favour of a certain decision, it is wise and proper to hear a counter-statement. You can have no idea how often and how much, under such an impression, I have desired that the marvellous descriptions which have reached me might prove, in some points, correct; and how frequently I have submitted myself to hot fires, to friction with magnets, to the passes of hands, etc., lest I should be shutting out discovery;—encouraging the strong desire that something might be true, and that I might aid in the development of a new force of nature.

Among those points of self-education which take up the form of *mental discipline*, there is one of great importance, and, moreover, difficult to deal with, because it involves an internal conflict, and equally touches our vanity and our ease. It consists in the *tendency to deceive ourselves* regarding all we wish for, and the necessity of *resistance to these desires*. It is impossible for any one who has not been constrained, by the course of his occupation and thoughts, to a habit of continual self-correction, to be aware of the amount of error in relation to judgment arising from this tendency. The force of the temptation which urges us to seek for such evidence and appearances as are in favour of our desires, and to disregard those which oppose them, is wonderfully great. In this respect we are all, more or less, active promoters of error. In place of practising wholesome self-abnegation, we ever make the wish the father to the thought: we receive as friendly that which agrees with, we resist with dislike that which opposes us; whereas the very reverse is required by every dictate of common sense. Let me illustrate my meaning by a case where the proof being easy, the rejection of it under the temptation is the more striking. In old times, a ring or a button would be tied by a boy to one end

of a long piece of thread, which he would then hold at the other end, letting the button hang within a glass, or over a piece of slate-pencil, or sealing-wax, or a nail; he would wait and observe whether the button swung, and whether in swinging it tapped the glass as many times as the clock struck last, or moved along or across the slate-pencil, or in a circle or oval. In late times, parties in all ranks of life have renewed and repeated the boy's experiment. They have sought to ascertain a very simple fact—namely, whether the effect was as reported; but how many were unable to do this? They were sure they could keep their hands immovable,—were sure they could do so whilst watching the result,—were sure that accordance of swing with an expected direction was not the result of their desires or involuntary motions. How easily all these points could be put to the proof by *not looking at the objects*, yet how difficult for the experimenter to deny himself that privilege. I have rarely found one who would freely permit the substance experimented with to be screened from his sight, and then its position changed.

When engaged in the investigation of table-turning, I constructed a very simple apparatus,* serving as an index, to show the unconscious motions of the hands upon the table. The results were either that the index moved before the table, or that neither index nor table moved; and in numerous cases all moving power was annihilated. A universal objection was made to it by the table-turners. It was said to paralyse the powers of the mind;—but the experimenters need not see the index; they may leave their friends to watch that, and their minds may revel in any power that their expectation or their imagination can confer. So restrained, a *dislike* to the trial arises; but what is that except a proof that whilst they trust themselves they doubt themselves, and are not willing to proceed to the decision, lest the trust which they like should fail them, and the doubt which they dislike rise to the authority of truth.

Again, in respect of the action of magnets on the body, it is almost impossible for an uninstructed person to enter profitably upon such an inquiry. He may observe *any* symptom which his expectation has been accidentally directed to: yet be

* *Athenæum*, July 2, 1853.—Newman, Philosophical Instrument Maker, 122 Regent Street (see Note F).

unconscious of any, if unaware of his subjection to the magnetic force, or of the conditions and manner of its application (see Note G).

As a proof of the extent of this influence, even on the minds of those well aware of its force, and desirous under every circumstance to escape from it, I will mention the practice of the chemist, who, dealing with the balance, that impartial decider which never fails in its indication, but offers its evidence with all simplicity, durability, and truth, still remembers he should doubt himself; and, with the desire of rendering himself inaccessible to temptation, takes a counterpoised but unknown quantity of the substance for analysis, that he may remain ignorant of the proportions which he ought to obtain, and only at last compares the sum of his products with his counterpoise.

The *inclination* we exhibit in respect of any report or opinion that harmonizes with our preconceived notions, can only be compared in degree with the *incredulity* we entertain towards everything that opposes them; and these opposite and apparently incompatible, or at least inconsistent, conditions are accepted simultaneously in the most extraordinary manner. At one moment a departure from the laws of nature is admitted without the pretence of a careful examination of the proof; and at the next, the whole force of these laws, acting undeviatingly through all time, is denied, because the testimony they give is disliked.

It is my firm persuasion, that no man can examine himself in the most common things, having any reference to him personally, or to any person, thought, or matter related to him, without being soon made aware of *the temptation* and the difficulty of opposing it. I could give you many illustrations personal to myself, about atmospheric magnetism, lines of force, attraction, repulsion, unity of power, nature of matter, etc.; or in things more general to our common nature, about likes and dislikes, wishes, hopes, and fears; but it would be unsuitable and also unnecessary, for each must be conscious of a large field sadly uncultivated in this respect. *I will simply express my strong belief, that that point of self-education which consists in teaching the mind to resist its desires and inclinations, until they are proved to be right, is the most important of all, not only in things of natural philosophy, but in every department of daily life.*

There are numerous precepts resulting more or less from the principles of mental discipline already insisted on as essential, which are very useful in forming a judgment about matters of fact, whether among natural things or between man and man. Such a precept, and one that should recur to the mind early in every new case is, to *know the conditions* of the matter, respecting which we are called upon to make a judgment. To suppose that any would judge before they professed to know the conditions would seem to be absurd; on the other hand, to assume that the community *does wait* to know the conditions before it judges, is an assumption so large that I cannot accept it. Very few search out the conditions; most are anxious to sink those which oppose their preconceptions; yet none can be left out if a right judgment is to be formed. It is true that many conditions must ever remain unknown to us, even in regard to the simplest things in nature: thus as to the wonderful action of gravity, whose law never fails us, we cannot say whether the bodies are acting truly at a distance, or by a physical line of force as a connecting-link between them. The great majority think the former is the case; Newton's judgment is for the latter.* But of the conditions which are within our reach we should search out all; for in relation to those which remain unknown or unsuspected, we are in that very ignorance (regarding judgment) which it is our present object, first to make manifest, and then to remove.

One exercise of the mind, which largely influences the power and character of the judgment, is the habit of forming *clear and precise ideas*. If, after considering a subject in our ordinary manner, we return upon it with the special purpose of noticing the condition of our thoughts, we shall be astonished to find how little precise they remain. On recalling the phenomena relating to a matter of fact, the circumstances modifying them, the kind and amount of action presented, the real or probable result, we shall find that the first impressions are scarcely fit for the foundation of a judgment, and that the second thoughts will be best. For the acquirement of a good condition of mind in this respect, the thoughts should be trained to a habit of clear and precise formation, so that vivid and distinct impres-

* *Newton's Works*, Horsley's Edition, 1783, iv, p. 438—or the Third Letter to Bentley.

sions of the matter in hand, its circumstances and consequences, may remain.

Before we proceed to consider any question involving physical principles, we should set out with *clear ideas* of the naturally possible and impossible. There are many subjects uniting more or less of the most sure and valuable investigations of science with the most imaginary and unprofitable speculation, that are continually passing through their various phases of intellectual, experimental, or commercial development: some to be established, some to disappear, and some to recur again and again, like ill weeds that cannot be extirpated, yet can be cultivated to no result as wholesome food for the mind. Such, for instance, in different degrees, are the caloric engine, the electric light, the Pasilalinic sympathetic compass,* mesmerism, homœopathy, odylism, the magneto-electric engine, the perpetual motion, etc.: all hear and talk of these things; all use their judgment more or less upon them, and all might do that effectively, if they were to instruct themselves to the extent which is within their reach. I am persuaded that natural things offer an admirable school for self-instruction, a most varied field for the necessary mental practice, and that those who exercise themselves therein may easily apply the habits of thought thus formed to a social use. As a first step in such practice, clear ideas should be obtained of what is possible and what is impossible (see Note I). Thus, it is impossible to *create* force. We may employ it; we may evoke it in one form by its consumption in another; we may hide it for a period; but we can neither *create* nor *destroy* it. We may cast it away; but where we dismiss it, there it will do its work. If, therefore, we desire to consider a proposition respecting the employment or evolution of power, let us carry our judgment, educated on this point, with us. If the proposal include the double use of a force with only one excitement, it implies a creation of power, and that *cannot be*. If we could by the fingers draw a heavy piece of wood or stone upward without effort, and then, letting it sink, could produce by its gravity an effort equal to its weight, that would be a creation of power, and *cannot be*.

So again we cannot *annihilate* matter, nor can we *create* it. But if we are satisfied to rest upon that dogma, what are we to

* See *Chambers's Journal*, 1851, Feb. 15th, p. 105 (see Note H).

think of table-lifting? If we could make the table to cease from acting by gravity upon the earth beneath it, or by reaction upon the hand supposed to draw it upwards, we *should annihilate it*, in respect of that very property which characterizes it as matter.

Considerations of this nature are very important aids to the judgment; and when a statement is made claiming our assent, we should endeavour to reduce it to some consequence which can be immediately compared with, and tried by, these or like compact and never-failing truths. If incompatibility appears, then we have reason to suspend our conclusion, however attractive to the imagination the proposition may be, and pursue the inquiry further, until accordance is obtained; it must be a most uneducated and presumptuous mind that can at once consent to cast off the tried truth and accept in its place the mere loud assertion. We should endeavour to separate the points before us, and concentrate each, so as to evolve a clear type idea of the ruling fact and its consequences; looking at the matter on every side, with the great purpose of distinguishing the constituent reality, and recognizing it under every variety of aspect.

In like manner we should accustom ourselves to clear and definite language, especially in physical matters, giving to a word its true and full, but measured meaning, that we may be able to convey our ideas clearly to the minds of others. Two persons cannot mutually impart their knowledge, or compare and rectify their conclusions, unless both attend to the true intent and force of language. If by such words as attraction, electricity, polarity, or atom, they imply different things, they may discuss facts, deny results, and doubt consequences for an indefinite time without any advantageous progress. I hold it as a great point in self-education that the student should be continually engaged in forming exact ideas, and in expressing them clearly by language. Such practice insensibly opposes any tendency to exaggeration or mistake, and increases the sense and love of truth in every part of life.

I should be sorry, however, if what I have said were understood as meaning that education for the improvement and strengthening of the judgment is to be altogether repressive of the imagination, or confine the exercise of the mind to processes

of a mathematical or mechanical character. I believe that, in the pursuit of physical science, the imagination should be taught to present the subject investigated in all possible, and even in impossible views; to search for analogies of likeness and (if I may say so) of opposition—inverse or contrasted analogies; to present the fundamental idea in every form, proportion, and condition; to clothe it with suppositions and probabilities, that all cases may pass in review, and be touched, if needful, by the Ithuriel spear of experiment. But all this must be *under government*, and the result must not be given to society until the judgment, educated by the process itself, has been exercised upon it. Let us construct our hypotheses for an hour, or a day, or for years; they are of the utmost value in the elimination of truth, "which is evolved more freely from error than from confusion"; but, above all things, let us not cease to be aware of the temptation they offer, or, because they gradually become familiar to us, accept them as established. We could not reason about electricity without thinking of it as a fluid, or a vibration, or some other existent state or form. We should give up half our advantage in the consideration of heat if we refused to consider it as a principle, or a state of motion. We could scarcely touch such subjects by experiment, and we should make no progress in their practical application, without hypothesis; still it is absolutely necessary that we should learn to doubt the conditions we assume, and acknowledge we are uncertain, whether heat and electricity are vibrations or substances, or either.

When the different data required are in our possession, and we have succeeded in forming a clear idea of each, the mind should be instructed to *balance them* one against another, and not suffered carelessly to hasten to a conclusion. This reserve is most essential; and it is especially needful that the reasons which are adverse to our expectations or our desires should be carefully attended to. We often receive truth from unpleasant sources; we often have reason to accept unpalatable truths. We are never freely willing to admit information having this unpleasant character, and it requires much self-control in this respect, to preserve us even in a moderate degree from errors. I suppose there is scarcely one investigator in original research who has not felt the temptation to disregard the reasons and

results which are against his views. I acknowledge that I have experienced it very often, and will not pretend to say that I have yet learned on all occasions to avoid the error. When a bar of bismuth or phosphorus is placed between the poles of a powerful magnet, it is drawn into a position across the line joining the poles; when only one pole is near the bar, the latter recedes; this and the former effect is due to repulsion, and is strikingly in contrast with the attraction shown by iron. To account for it, I at one time suggested the idea that a polarity was induced in the phosphorus or bismuth the reverse of the polarity induced in iron, and that opinion is still sustained by eminent philosophers. But observe a necessary result of such a supposition, which appears to follow when the phenomena are referred to elementary principles. *Time* is shown, by every result bearing on the subject, to be concerned in the coming on and passing away of the inductive condition produced by magnetic force, and the consequence, as Thomson pointed out, is, that if a ball of bismuth could be suspended between the poles of a magnet, so as to encounter no resistance from the surrounding medium, or from friction or torsion, and were once put in motion round a vertical axis, it would, because of the assumed polar state, go on for ever revolving, the parts which at any moment are axial moving like the bar, so as to become the next moment equatorial. Now, as we believe the mechanical forces of nature tend to bring things into a stable, and not into an unstable condition; as we believe that a perpetual motion is impossible; so because both these points are involved in the notion of the reverse polarity, which itself is not supposed to be dependent on any consumption of power, I feel bound to hold the judgment balanced, and therefore hesitate to accept a conclusion founded on such a notion of the physical action; the more especially as the peculiar test facts * which prove the polarity of iron are not reproduced in the case of diamagnetic bodies (see Note K).

As a result of this wholesome mental condition, we should be able to form a *proportionate judgment*. The mind naturally desires to settle upon one thing or another; to rest upon an affirmative or a negative; and that with a degree of absolutism which is irrational and improper. In drawing a conclusion it

* *Experimental Researches in Electricity*, paragraphs 2657–2681.

is very difficult, but not the less necessary, to make it *proportionate* to the evidence: except where certainty exists (a case of rare occurrence), we should consider our decisions as probable only. The probability may appear very great, so that in affairs of the world we often accept such as certainty, and trust our welfare or our lives upon it. Still, only an uneducated mind will confound probability with certainty, especially when it encounters a contrary conclusion drawn by another from like data. This suspension in degree of judgment will not make a man less active in life, or his conclusions less certain as truths; on the contrary, I believe him to be the more ready for the right amount and direction of action on any emergency; and am sure his conclusions and statements will carry more weight in the world than those of the incautious man.

When I was young, I received from one well able to aid a learner in his endeavours toward self-improvement, a curious lesson in the mode of estimating the amount of belief one might be induced to attach to our conclusions. The person was Dr. Wollaston, who, upon a given point, was induced to offer me a wager of two to one on the affirmative. I rather impertinently quoted Butler's well-known lines * about the kind of persons who use wagers for argument, and he gently explained to me, that he considered such a wager not as a thoughtless thing, but as an expression of the amount of belief in the mind of the person offering it; combining this curious application of the wager, as a *meter*, with the necessity that ever existed of drawing conclusions, not absolute but proportionate to the evidence (see Note L).

Occasionally and frequently the exercise of the judgment ought to end in *absolute reservation.* It may be very distasteful, and great fatigue, to suspend a conclusion, but as we are not infallible, so we ought to be cautious; we shall eventually find our advantage, for the man who rests in his position is not so far from right as he who, proceeding in a wrong direction, is ever increasing his distance. In the year 1824, Arago discovered † that copper and other bodies placed in the vicinity of a magnet, and having no direct action of attraction or

* "Quoth she, 'I've heard old cunning stagers,
Say fools for arguments use wagers.'"

† *Annales de Chimie*, xxviii, p. 325.

repulsion upon it, did affect it when moved, and was affected by it. A copper plate revolving near a magnet carried the magnet with it; or if the magnet revolved, and not the copper, it carried the copper with it. A magnetic needle vibrating freely over a disc of glass or wood, was exceedingly retarded in its motion when these were replaced by a disc of copper. Arago stated most clearly all the conditions, and resolved the forces into three directions, but not perceiving the physical cause of the action, exercised a most wise and instructive reservation as to his conclusion. Others, as Haldat, considered it as the proof of the universality of a magnetism of the ordinary kind, and held to that notion though it was contradicted by the further facts; and it was only at a future period that the true physical cause, namely, magneto-electric currents induced in the copper, became known to us.* What an education Arago's mind must have received in relation to philosophical reservation; what an antithesis he forms with the mass of table-turners; and what a fine example he has left us of that condition of judgment to which we should strive to attain!

If I may give another illustration of the needful reservation of judgment, I will quote the case of oxygen and hydrogen gases, which, being mixed, will remain together uncombined for years in contact with glass, but in contact with spongy platinum combine at once (see Note M). We have the same fact in many forms, and many suggestions have been made as to the mode of action, but as yet we do not know *clearly* how the result comes to pass. We cannot tell whether electricity acts or not. Then we should suspend our conclusions. Our knowledge of the fact itself, and the many varieties of it, is not the less abundant or sure; and when the truth shall hereafter emerge from the mist, we ought to have no opposing prejudice, but be prepared to receive it.

The education which I advocate will require *patience* and *labour of thought* in every exercise tending to improve the judgment. It matters not on what subject a person's mind is occupied, he should engage in it with the conviction that it will require mental labour. A powerful mind will be able to draw a conclusion more readily and more correctly than one of moderate character, but both will surpass themselves if they

* *Philosophical Transactions*, 1832, p. 146.

make an earnest, careful investigation, instead of a careless or prejudiced one; and education for this purpose is the more necessary for the latter, because the man of less ability may, through it, raise his rank and amend his position. I earnestly urge this point of self-education, for I believe it to be more or less in the power of every man greatly to improve his judgment. I do not think that one has the complete capacity for judgment which another is naturally without. I am of opinion that all may judge, and that we only need to declare on every side the conviction that mental education is wanting, and lead men to see that through it they hold, in a large degree, their welfare and their character in their own hands, to cause in future years an abundant development of right judgment in every class.

This education has for its first and its last step *humility*. It can commence only because of a conviction of deficiency; and if we are not disheartened under the growing revelations which it will make, that conviction will become stronger unto the end. But the humility will be founded, not on comparison of ourselves with the imperfect standards around us, but on the increase of that internal knowledge which alone can make us aware of our internal wants. The first step in correction is to learn our deficiencies, and having learned them, the next step is almost complete: for no man who has discovered that his judgment is hasty, or illogical, or imperfect, would go on with the same degree of haste, or irrationality, or presumption as before. I do not mean that all would at once be cured of bad mental habits, but I think better of human nature than to believe that a man in any rank of life, who has arrived at the consciousness of such a condition, would deny his common sense, and still judge and act as before. And though such self-schooling must continue to the end of life to supply an experience of deficiency rather than of attainment, still there is abundant stimulus to excite any man to perseverance. What he has lost are things imaginary, not real; what he gains are riches before unknown to him, yet invaluable; and though he may think more humbly of his own character, he will find himself at every step of his progress more sought for than before, more trusted with responsibility and held in pre-eminence by his equals, and more highly valued by those whom he himself will esteem worthy of approbation.

And now a few words upon the mutual relation of two classes, namely, *those* who decline to educate their judgments in regard to the matters on which they decide, and those who, by self-education, have endeavoured to improve themselves; and upon the remarkable and somewhat unreasonable manner in which the latter are called upon, and occasionally taunted, by the former. A man who makes assertions, or draws conclusions, regarding any given case, ought to be competent to investigate it. He has no right to throw the onus on others, declaring it their duty to prove him right or wrong. His duty is to demonstrate the truth of that which he asserts, or to cease from asserting (see Note N). The men he calls upon to consider and judge have enough to do with themselves, in the examination, correction, or verification of their own views. The world little knows how many of the thoughts and theories which have passed through the mind of a scientific investigator have been crushed in silence and secrecy by his own severe criticism and adverse examination; that in the most successful instances not a tenth of the suggestions, the hopes, the wishes, the preliminary conclusions have been realized. And is a man so occupied to be taken from his search after truth in the path he hopes may lead to its attainment, and occupied in vain upon nothing but a broad assertion?

Neither has the assertor of any new thing a right to claim an answer in the form of *Yes* or *No;* or think, because none is forthcoming, that he is to be considered as having established his assertion. So much is unknown to the wisest man that he may often be without an answer: as frequently he is so, because the subject is in the region of hypothesis, and not of facts. In either case he has the right to refuse to speak. I cannot tell whether there are two fluids of electricity or any fluid at all. I am not bound to explain how a table tilts any more than to indicate how, under the conjurer's hands, a pudding appears in a hat. The means are not known to me. I am persuaded that the results, however strange they may appear, are in accordance with that which is truly known, and if carefully investigated would justify the well-tried laws of nature; but, as life is limited, I am not disposed to occupy the time it is made of in the investigation of matters which, in what is known to me of them, offer no reasonable prospect of

any useful progress, or anything but negative results. We deny the right of those who call upon us to answer their speculations "*if we can*," whilst we have so many of our own to develop and correct; and claim the right for ourselves of withholding either our conclusions or the reasons for them, without in the least degree admitting that their affirmations are unanswerable. We are not even called upon to give an answer to the best of our belief: nor bound to admit a bold assertion because we do not *know* to the contrary. No one is justified in claiming our assent to the spontaneous generation of insects, because we cannot circumstantially explain how a mite or the egg of a mite has entered into a particular bottle. Let those who affirm the exception to the general law of nature, or those others who upon the affirmation accept the result, work out the experimental proof. It has been done in this case by Schulze,* and is in the negative; but how few among the many who make, or repeat, the assertion, would have the requisite self-abnegation, the subjected judgment, the perseverance, and the precision which has been displayed in that research.

When men, more or less marked by their advance, are led by circumstances to give an opinion adverse to any popular notion, or to the assertions of any sanguine inventor, nothing is more usual than the attempt to neutralize the force of such an opinion by reference to the mistakes which like educated men have made; and their occasional misjudgments and erroneous conclusions are quoted, as if they were less competent than others to give an opinion, being even disabled from judging like matters to those which are included in their pursuits by the very exercise of their minds upon them. How frequently has the reported judgment of Davy, upon the impossibility of gas-lighting on a large scale, been quoted by speculators engaged in tempting monied men into companies, or in the pages of journals occupied with the popular fancies of the day; as if an argument were derivable from that in favour of some special object to be commended. Why should not men taught in the matter of judgment far beyond their neighbours, be expected to err sometimes, since the very education in which they are advanced can only terminate with their lives? What is there about them, derived from *this education*, which sets up

* MÜLLER'S *Physiology*, or POGGENDORF'S *Annalen*, 1836, xxxix, p. 487.

the shadow of a pretence to perfection? Such men cannot learn all things, and may often be ignorant. The very progress which science makes amongst them as a body is a continual correction of ignorance—i.e. of a state which is ignorance in relation to the future, though wisdom and knowledge in relation to the past. In 1823, Wollaston discovered that beautiful substance which he called Titanium, believing it to be a simple metal: and it was so accepted by all philosophers. Yet this was a mistake, for Wöhler,* in 1850, showed the substance was a very compound body. This is no reproach to Wollaston or to those who trusted in him; he made a step in metallurgy which advanced knowledge, and perhaps we may hereafter, through it, learn to know that metals are compound bodies. Who, then, has a right to quote his mistake as a reproach against him? Who could correct him but men intellectually educated as he himself was? Who does not feel that the investigation remains a bright gem in the circlet that memory offers to his honour?

If we are to estimate the utility of an educated judgment, do not let us hear merely of the errors of scientific men, which have been corrected by others taught in the same careful school; but let us see what, as a body, they have produced, compared with that supplied by their reproachers. Where are the established truths and triumphs of ring-swingers, table-turners, table-speakers? What one result in the numerous divisions of science or its applications can be traced to their exertions? Where is the investigation completed, so that, as in gas-lighting, all may admit that the principles are established and a good end obtained, without the shadow of a doubt?

If we look to electricity, it, in the hands of the careful investigator, has advanced to the most extraordinary results: it approaches at the motion of his hand; bursts from the metal; descends from the atmosphere; surrounds the globe: it talks, it writes, it records, it appears to him (cautious as he has learned to become) as a universal spirit in nature. If we look to photography, whose origin is of our own day, and see what it has become in the hands of its discoverers and their successors, how wonderful are the results! The light is made to yield impressions upon the dead silver or the coarse paper, beautiful

* *Annales de Chimie*, xxix, p. 166.

as those it produced upon the living and sentient retina: its most transient impression is rendered durable for years; it is made to leave a visible or an invisible trace; to give a result to be seen now or a year hence; made to paint all natural forms and even colours (see Note O); it serves the offices of war, of peace, of art, science, and economy: it replaces even the mind of the human being in some of its lower services; for a little camphine lamp is set down and left to itself, to perform the duty of watching the changes of magnetism, heat, and other forces of nature, and to record the results, in pictorial curves, which supply an enduring record of their most transitory actions.

What has clairvoyance, or mesmerism, or table-rapping done in comparison with results like these? What have the snails at Paris told us from the snails at New York (see Note G)? What have any of these intelligences done in *aiding* such developments? Why did they not inform us of the possibility of photography? or when that became known, why did they not favour us with some instructions for its improvement? They all profess to deal with agencies far more exalted in character than an electric current or a ray of light: they also deal with mechanical forces; they employ both the bodily organs and the mental; they profess to lift a table, to turn a hat, to see into a box, or into the next room, or a town:—why should they not move a balance, and so give us the element of a new mechanical power? take cognizance of a bottle and its contents, and tell us how they will act upon those of a neighbouring bottle? either see or feel into a crystal, and inform us of what it is composed? Why have they not added one metal to the fifty (see Note N) known to mankind, or one planet to the number daily increasing under the observant eye of the astronomer? Why have they not corrected one of the *mistakes* of the philosophers? There are no doubt very many that require it. There has been plenty of time for the development and maturation of some of the numerous public pretences that have risen up in connexion with these supposed agencies; how is it that not one new power has been added to the means of investigation employed by the philosophers, or one valuable utilitarian application presented to society?

In conclusion, I will freely acknowledge that all I have said regarding the great want of judgment manifested by society

as a body, and the high value of any means which would tend to supply the deficiency, have been developed and declared on numerous occasions, by authority far above any I possess. The deficiency is known hypothetically, but I doubt if in reality; the individual acknowledges the state in respect of others, but is unconscious of it in regard to himself. As to the world at large, the condition is accepted as a necessary fact; and so it is left untouched, almost ignored. I think that education in a large sense should be applied to this state of the subject, and that society, though it can do little in the way of communicated experience, can do much, by a declaration of the evil that exists and of its remediable character; by keeping alive a sense of the deficiency to be supplied; and by directing the minds of men to the practice and enlargement of that self-education which every one pursues more or less, but which under conviction and method would produce a tenfold amount of good. I know that the multitude will always be behindhand in this education, and to a far greater extent than in respect of the education which is founded on book learning. Whatever advance books make, they retain; but each new being comes on to the stage of life, with the same average amount of conceit, desires, and passions, as his predecessors, and in respect of self-education has all to learn. Does the circumstance that we can do little more than proclaim the necessity of instruction justify the ignorance? or our silence? or make the plea for this education less strong? Should it not, on the contrary, gain its strength from the fact that all are wanting more or less? I desire we should admit that, as a body, we are universally deficient in judgment. I do not mean that we are utterly ignorant, but that we have advanced only a little way in the requisite education, compared with what is within our power.

If the necessity of the education of the judgment were a familiar and habitual idea with the public, it would often afford a sufficient answer to the statement of an ill-informed or incompetent person; if quoted to recall to his remembrance the necessity of a mind instructed in a matter, and accustomed to balance evidence, it might frequently be an answer to the individual himself. Adverse influence might, and would, arise from the careless, the confident, the presumptuous, the hasty, and the dilatory man, perhaps extreme opposition; but I

believe that the mere acknowledgment and proclamation of the ignorance, by society at large, would, through its moral influence, destroy the opposition, and be a great means to the attainment of the good end desired (for if no more be done than to lead such to turn their thoughts inwards, a step in education is gained) if they are *convinced* in any degree, an important advance is made; if they learn only to *suspend* their judgment, the improvement will be one above price.

It is an extraordinary thing that man, with a mind so wonderful that there is nothing to compare with it elsewhere in the known creation, should leave it to run wild in respect of its highest elements and qualities. He has a power of comparison and judgment, by which his final resolves, and all those acts of his material system which distinguish him from the brutes, are guided:—shall he omit to educate and improve them when education can do much? Is it towards the very principles and privileges that distinguish him above other creatures, he should feel indifference? Because the education is internal, it is not the less needful; nor is it more the duty of a man that he should cause his child to be taught than that he should teach himself. Indolence may tempt him to neglect the self-examination and experience which form his school, and weariness may induce the evasion of the necessary practices; but surely a thought of the prize should suffice to stimulate him to the requisite exertion: and to those who reflect upon the many hours and days, devoted by a lover of sweet sounds, to gain a moderate facility upon a mere mechanical instrument, it ought to bring a correcting blush of shame, if they feel convicted of neglecting the beautiful living instrument, wherein play all the powers of the mind.

I will conclude this subject;—believe me when I say I have been speaking from self-conviction. I did not think this an occasion on which I ought to seek for flattering words regarding our common nature; if so, I should have felt unfaithful to the trust I had taken up; so I have spoken from experience. In thought I hear the voice, which judges me by the precepts I have uttered I know that I fail frequently in that very exercise of judgment to which I call others; and have abundant reason to believe that much more frequently I stand manifest to those around me, as one who errs, without being corrected

by knowing it. I would willingly have evaded appearing before you on this subject, for I shall probably do but little good, and may well think it was an error of judgment to consent: having consented, my thoughts would flow back amongst the events and reflections of my past life, until I found nothing present itself but an open declaration, almost a confession, as the means of performing the duty due to the subject and to you.

NOTE REFERRED TO ON p. 47.

As an illustration of the present state of the subject, I will quote one letter from among many like it which I have received —M. F.

"————, *April* 5, 1854.

"SIR,—I am one of the clergymen of this parish, and have had the subject of table-turning brought under my notice by some of my younger parishioners; I gave your solution of it as a sufficient answer to the mystery. The reply was made, that you had since seen reason to alter your opinion. Would you have the politeness to inform me if you have done so? With many apologies for troubling you,

"I am, your obedient servant,

"———— ——."

(See also Note Q.)

NOTES REFERRED TO BY CAPITAL LETTERS IN PROFESSOR FARADAY'S LECTURE—E. R. L.

NOTE A.—Since the date at which Faraday wrote, it has been found that certain forces may possibly modify, not "the law of gravitation," but the net result of its operation in agglomerations of matter. Thus the pressure exerted upon bodies by light from the sun—though its repulsive effect is so small as to be negligible in the case of a body of which the illuminated surface is minute as compared with its mass (as, for instance, spheres of such size as the planets and fixed stars) yet becomes appreciable when the illuminated surface is greatly increased in proportion to the mass of the body under observation, as in the case of particles of the size of very fine powder. The light pressure on the earth's surface amounts to 74,000 tons, literally "negligible" when opposed to the earth's weight, which is six thousand million times a billion tons! Professor Poynting has shown that if the earth were subdivided into spheres, each of one forty-seven-billionth of its present radius, and were spread out in a thin layer so that each should receive on its surface the impact of sunshine - then the total light pressure of the sun on the surface of the particles so produced would just equal the gravitational pull. The particles supposed to be produced would have a diameter of about one-millionth of an inch. The material of the earth would then *apparently* fail to obey the law of gravitation. Similarly, each particle of cosmic dust (such as actually exists in vast quantity, and is a normal part of the Solar System) must be subject to the action of the sun's light rays antagonizing its gravitational attraction. Thus it might be contended by a rash critic that the law of gravitation is not to be applied universally. Clearly, however, the interference with gravitational attraction by the pressure of light

does not justify any such conclusion. Both light repulsion and gravitational attraction are operative, and the result is the difference of their respective pull and push. This is merely one of the innumerable and necessary instances of the summation and balancing of effects due to interacting causes with which the student of nature is familiar.

NOTE B.—It must be remembered that at the time when Faraday adduced organic form as an illustration of the permanency of natural law, the doctrine of organic evolution had not been generally accepted. His statement would be modified at the present day by the recognition of the fact that organic forms have been slowly altered in the course of ages by very slight changes—so slight as to be scarcely perceptible by the human observer of a few succeeding generations, yet accumulating in the course of ages so as to lead to the production and establishment of new species, and in longer lapses of time to the derivation of the most complex living things from simpler ancestors, and of these again from yet simpler forms.

NOTE C.—The man who to-day considers the ceaseless yet certain actions located in a blade of grass, recognizes, not his inability to change the character of the least among them, but his ability by "crossing" and the selection of modified offspring for further breeding, to bring about marked changes in some, at least, of the minor characters presented by those actions. The statement as to the long-enduring persistence of the natural characters of organic species is correct, but we no longer accept a general doctrine of the *absolute* permanency of the characters produced by natural forces—though we still adhere (with some reservations) to the doctrines of the persistence of "force" and the indestructibility of "matter."

NOTE D.—With a sufficiently large voltaic battery there is certainly a spark visible when the wires approach. Though air is practically a non-conductor, a current may be forced through it with sufficiently high electrical pressure or "voltage." The passage of a current through air is accompanied by a spark which is due to a sudden disruption of the highly resistent or "non-conducting" atmosphere. Faraday explains in his *Experimental Researches* that inasmuch as the voltaic metal couple will send a current through a highly conducting circuit, he expected a slight amount to flow through the air if the length of the air-path were made sufficiently small: and the surmise is perfectly correct. His doubt can only have been due to the low pressure or voltage which was at his command and the consequent weakness of the spark. Nowadays, with voltaic batteries of enormous energy, the spark can be easily seen (and heard) by a large audience at a distance.

NOTE E.—Later investigation has shown that electric conduction is a complex process both in solids and liquids, and that the phrase "conduction proper" must not be applied equally to solid silver and to a solution of a salt or to a "fused" substance. The occurrence of electrolytic decomposition in liquids at once suggests that conduction in such liquids differs in kind from that in solid metal. It is interesting to note that Faraday was himself the first to point this out. If one observes what occurs in a certain few non-conducting solids, one finds that they conduct only when melted. Thus, relatively, ice insulates and water conducts. One might come to the conclusion that the state of "liquidity" governs the phenomenon, and by some it would be considered a hair-splitting distinction to say that it is heat and not the "liquidity" that governs. If the state which we call "fluid" always accompanies the power to conduct, a certain type of mind is satisfied to look no further. But the method of "concomitant variation" requires careful anaylsis of the phenomena which show concomitant variation, if the method is to lead us to a safe conclusion as to the cause or causes at work. The discovery of substances such as cerium oxide and boron (which appreciably "conduct"

only when heated, whilst yet remaining solid) exposes the danger of coming to a conclusion when the facts have not been fully examined. That discovery renders it obvious that the conductivity acquired by certain bodies when brought into the liquid condition by the application of heat does not depend upon the assumption of the liquid state, but upon other consequences of increased temperature of which "liquidity" is only one, and not a necessary antecedent in all cases, of the acquirement of electric conductivity. Minds untrained in the analysis of phenomena by means of experimental investigation and the consequent determination of the relations to one another of a large series of facts, are apt to accept as demonstrated conclusions what are merely probable or possible hypotheses. The study of philology and of human history fails to train the mind in the definite ascertainment of a large number of relations among facts. The facts dealt with in those studies are related in apparently arbitrary ways which defy the efforts of philologists and historians to trace perfectly consequential laws of cause and effect. It is on this account, among others, that those studies are of little value as mental training, compared with the experimental sciences, the votaries of which have in hypothesis and verification by experiment an almost unlimited power of ascertaining the innumerable relations of a whole universe of facts, and find in the consequent joy of the creation of new knowledge and understanding, an unceasing stimulation to the exercise of that power.

NOTE F.—The original model of "the very simple apparatus" made by Faraday for the purpose of showing the unconscious pressure of the hands upon the table in what was called "table-turning" was given by him to my father in 1855—and was for a long time in my possession. It consisted of two sheets of stiff millboard of royal octavo size, between which were laid, at right angles to the length of the boards, two cylindrical glass rods, each about five inches long and three-tenths of an inch in diameter. The upper board was thus supported on the glass rods, which acted as rollers. It was freely movable upon them to and fro when one placed the tips of the fingers of one or both of one's hands lightly on the board. A couple of elastic india-rubber bands were passed round the two boards transversely to their length so as to bind the boards together, but yet to allow of free back and forth movement of the upper board and to permit by the elasticity of the bands a small amount of lateral displacement. Faraday, having had several of his little pieces of apparatus manufactured, now invited would-be "table-turners" to make use of it. Such a "planchette" (as it was subsequently termed) was placed on the table beneath the fingers of each operator in a "table-turning" experiment, and it was found that whereas in previous experiments without a planchette the table had been made to move by the hands lightly resting on it, now there was no movement of the table but a slight forward displacement, more or less conspicuous, of the upper board of the planchette as it moved on its glass rollers under the gentle pressure of the operator's fingers. In this way Faraday showed that it was possible for honest experimenters to apply unconsciously a slight push to a table, and so for their united unconscious efforts to cause it to move or turn in a manner which was to them mysterious and supernatural, whereas when their fingers were separated from the table by the mobile planchette the "push" in each case merely caused the upper board of that little intermediary to move instead of acting upon the table itself. By the irony of human fate, Faraday's detective "planchette" was subsequently fitted with a pencil and used by "occultists" to obtain writing caused by the unconscious, though sometimes conscious, direction of its movements by the hands of an inquirer lightly laid on it. Such writing was interpreted by the "occultists" as "messages from the spirit world." On the other hand, "planchette-writing" and similar experimental methods offer to the psychologist a valuable

means of exploring the directive movements given unconsciously to the muscles of the body by the brain in many persons when thus subjected to properly guarded and well-devised experiment.

NOTE G.—I may refer the reader to the account given in my little book, *From an Easy Chair* (Constable, 1909), p. 60, of a decisive experiment on this subject made by me in Charcot's laboratory at the Salpêtrière Hospital some thirty years ago. A female out-patient there was supposed to acquire anæsthesia or want of sensation in the arm by holding in her hand a bar of iron connected with a voltaic battery so that the bar became magnetized when the battery was in action. At other times her arm and hand were proved to be normally sensitive. But when the iron bar was magnetized, sensation disappeared and (her face being turned away so that she could not see what was being done) large carpet needles were run into and through her hand and arm without causing in her the slightest indication of pain or of any knowledge that she had been pierced by the needles. The iron bar was held in the girl's hand for some minutes, and then the "making" of it into a magnet by allowing the electric current to pass to it was directed by Charcot himself, who gave "the word of command." At once, as the students and visitors saw and established by pricking the girl's arm with needles, there was apparently a complete loss of sensation, which returned, however, as soon as (by Charcot's spoken order) the electric current was stopped and the iron bar ceased to be a magnet. The tests were sufficiently severe and numerous, and watched with such care on various successive days, as to make it extremely improbable that the girl was pretending to insensibility. It is well established that such insensibility can be effectively produced in various ways. The question here was, "Is it due to the action of a magnet?" By chance, after witnessing this experiment with Charcot, I had, and took, the opportunity of emptying the voltaic battery in use, when the room was cleared and no other person was present except a medical friend whom I took into my confidence as witness. An hour or so later Charcot returned with other visitors and the patient to repeat the demonstration. So when the emphatic order was given to "make contact" and the voltaic current was believed by Charcot's assistants and by every one present (except my medical friend and myself) to have made the iron bar into a magnet, no current passed, and the bar was not magnetized. Nevertheless the girl's arm was "anæsthetized" as usual with complete success, and the demonstration was as convincing as ever. The "suggestion" and conviction in the girl's mind set up by Charcot's word of command, "Make contact," was sufficient. There was no "magnetism" in operation at all, but merely the suggestion to her that the bar had become a magnet and that it being a magnet, her arm must, of course, become insensitive. I explained, with apologies to Charcot, what I had done, and his assistants at once verified the fact that the voltaic battery had been put out of action. The experiment was a decisive one, and I was at once forgiven by the great physician for the liberty I had taken and congratulated on having carried it through.

NOTE H.—The various wonderful things here cited by Faraday as being heard and talked about by all in 1854, are, some of them, familiar to us under the same names sixty-two years later. But not all are familiar. In a later part of his discourse he speaks of "ring-swingers, table-turners, table-speakers"—names which, with perhaps the exception of the second, are not familiar at the present day. "Ring-swinging," I may say, was a mode of "divination" to be classed with "Bible-swinging" and the throwing of rods and other appeals to "chance," the revelations of which were supposed to be influenced by the interference of a tutelary deity, or demon. I am informed by Prof. Perry, F.R.S., that the old "caloric engine" mentioned by Faraday is now called the gas-engine or the petrol-engine or the Diesel motor. There has been no change in

principle since 1852, but a great change in methods of applying the principle. These air-engines of 1851–4 were called heat-engines by men like Rankine and Thomson, but they were called caloric engines by the general public, especially in America. If an American had spoken of a "caloric engine" in 1854, he would have meant Ericsson's air-engine, which was used to drive a boat. The "electric light" and the "magneto-electric machine" are, of course, great inventions which have now come into general use and vast importance. "Mesmerism," about which much that was fanciful and incorrect was, at one time, believed, is better known to-day under the name "hypnotism," and is concerned with a very real and remarkable mental condition, the study of which has yielded and is still yielding most important results. "Homœopathy," in so far as it was the assertion that physiological disorders must be "cured" by drugs which produce similar disorders has been experimentally tested and rejected: it is no longer entertained as a serious proposition. "Odylism" has vanished into obscurity. It was the assertion of the existence of a mysterious force, called "odyl," by the Baron von Reichenbach in 1845, supposed to be connected with certain crystals, magnets, and the human body. The supposed facts brought forward by believers in this mysterious force were long ago shown to be illusions due in some instances to fraud and in others to hypnotic suggestion. Varieties of this form of illusion still flourish at the present day. "Perpetual motion" refers to the attempt to construct a piece of mechanism which, once set going, shall perpetually go on producing useful work without drawing on any external source of energy. In the eighteenth century the attempt excited a good deal of attention, but it is now recognized, after examination of a vast variety of proposed apparatus, that the result sought is one which is a contradiction of the fundamental laws of matter and motion. "The Pasilalinic sympathetic compass" is perhaps the most foolish and ridiculous of all the fanciful pretences to discovery cited by Faraday. According to the article in *Chambers's Journal*, 1851, referred to by Faraday, a translation from the French of a M. Jules Allix, two French experimenters had discovered that individuals of the common snail have a mysterious sympathy with one another, and actually influence at a distance and determine the movements of other snails—even at a great distance. These experimenters are related to have shown that snails kept under observation in New York cause "sympathetic" movements corresponding to their own in similar snails kept in Paris. The "experimenters" state that they suppose that threads like the gossamer of spiders issue from snails and keep them in communication with one another, and that these threads are infinitely fine and invisible, and can be extended to such vast length as to connect snails separated from one another by the Atlantic Ocean. Accordingly the "discoverers" of this invisible connexion between widely separated snails introduce for their pretended discovery the name "Pasilalinic—which is being translated "universal talking—sympathetic compass." The whole story is obviously rubbish. But whether it was a hoax which was played on the editor of *Chambers's Journal* or a jocose parody of the effusions of the mesmerists and "odylists" of the day, does not appear. Had it first appeared in recent years it might reasonably be regarded as a burlesque of the assertions of the believers in "thought transference" and "brain-waves" and their pretentious invention of the word "telepathy," which is fairly matched by the word "Pasilalinic." Faraday refers again to the snails on page 64.

NOTE I. –Faraday here speaks of "clear ideas as to what is possible and what is impossible." The terms "possible" and "impossible" are liable to lead to misconception, and as a rule they are to be avoided in the discussion of narratives of extraordinary or marvellous occurrences. A statement of a supposed occurrence may be logically absurd. It may involve a contradiction

in terms, and then it would be correct to call the supposed occurrence "impossible." But it is generally recognized at the present day that the proper attitude of the scientific inquirer when confronted with the narration of a supposed marvel is not the consideration of its improbability or impossibility, but simply the taking of steps to decide whether the fact is or is not as narrated. He must demand the evidence in favour of the supposed marvel and examine it and determine its value. If he thinks the narration so highly improbable and the persons who make it so little likely to be correct in their observation and statement that his time will be wasted if given to its examination he can, of course, decline to occupy himself with the matter. But he is not justified in stating that the occurrence is "impossible" and that on that account he will not inquire into it, unless it is in its terms a logical absurdity or else necessarily involves the direct denial of some established principle which he can at once demonstrate to be operative in this particular matter. An impressive warning as to the need for great caution in using the unqualified word "impossible" is furnished by the example given by the French philosopher, Comte, of something "which is conceivable and yet is now for ever impossible." He gave as his example a knowledge as to what chemical elements are present in the sun and stars -a thing readily conceivable, but for ever, he said, out of the bounds of possibility. Within twelve years of Comte's assertion the determination of the bright lines characteristic of each of the chemical elements as shown by the spectroscope when applied to the light given off by each of them in the incandescent condition was made known, and these lines were found to be identical with lines in the spectrum of the light of the sun and some fixed stars. By this identification the presence of certain chemical elements in the heavenly bodies was ascertained, and what Comte had chosen as an example of something impossible though conceivable was accomplished. On the other hand, we say it is "impossible" to create force or annihilate matter, because such proceedings involve a contradiction in terms. When we say this we use the words "create" and "annihilate" in a strict sense as terms defined to mean operations beyond human experience and power. In a less strict and secondary, somewhat figurative sense, we are justified in saying that we continually "create" and "annihilate" both matter and force—that is to say, we cause matter and force to *appear* or become obvious to our senses here and now in various forms. On other occasions we cause them to disappear. Even Milton did not imagine "the creation" of animals out of nothing, but described it as a transformation of existing matter—a "bringing forth" or birth from the womb of the earth. But the physical philosopher uses the terms "create" and "annihilate" in a strict and absolute sense—meaning "produce from nothing" and "reduce to nothing"—and rightly does not hesitate to assert that they are both "impossibilities."

NOTE K.—This question has been answered by the modern theory of "permeability." It is not a matter of polarities. Iron is more highly permeable than a vacuum, that is to say, than ether unaffected by the presence of matter, whilst bismuth is less permeable than ether.

NOTE L.—In an article published in the *Rationalist Press Association's Annual* for 1915 with the title "Science and the Limits of Belief," I wrote as follows, without any recollection at the time of the advocacy by the great Faraday of a numerical expression of "the amount of belief" in the mind of one who as a rule contents himself with vaguely indicating that he believes this or that:

"Turning now from the specific question of belief in ghosts or spirits to the question of belief in general, we must all admit that the word 'belief' is a misleading one, since it is applied to a condition of mind which presents such varieties of intensity that, unless some measure of that intensity is given by one who uses it, there are apt to be confusion and misunderstanding. When

a man wishes to express the highest degree of conviction as to some future occurrence—for instance, that the sun will appear above the horizon to-morrow—he says that he has the 'belief' that it will do so. He 'believes,' or has the belief, that all living things, including himself, will sooner or later die. He 'believes' that if he throws a heavy body into the air it will fall to the ground. But if he is asked whether a friend is in London about whose movements he is incompletely informed, he will say: 'I believe that he is.' He will say that he has the 'belief' that it is 'unlucky' to start on a journey on a Friday, or to sit down to dinner in a party of thirteen.

"It is clear that these 'beliefs' are of very different degrees of intensity, and it would often help towards the definite expression of one's state of mind were separate words used to convey the degrees of intensity of a belief, or if a numerical scale were used for the purpose like that of a thermometer. One would say of those beliefs which are based on demonstration and repeated verification, or on the probability of the continuation of the order of events observed by mankind from time immemorial: 'My belief about this is 100.' With regard to some probabilities one would place it at 85: or, again, at 50 (an even 'chance,' as it is called). And so on down to 5, 3, and 1, the last indicating the merest inkling of a belief, and 0 meaning no 'belief' at all. Then we should come to beliefs below zero—namely, greater or less intensity of the 'belief' that the thing propounded or the conditions leading to its occurrence do not exist. It would be of some interest to the student of the human mind were educated men who express their 'belief' in the 'existence' of ghostly 'entities' and 'discarnate intelligences interacting with us on the material side' willing to classify their 'beliefs' by reference to such a scale.

"An important feature about the intensity of a belief is that it exists often at a very high degree in persons who admit that they are unable to give reasonable ground for that belief, and are unable to state how they have become possessed of it. The emotional conditions of hope, fear, love, and hate produce this result, and are excited by rhetoricians in order to implant beliefs in their hearers' minds. Similar is the effect of that remarkable suspension of the reasoning process and subjection of the mind to 'suggestion' which is called 'hypnotism.' The intensity of the 'beliefs' suggested by external agents to an individual whose brain is in the 'hypnotized' condition (resembling, if not identical with, that which occurs in sleep-walking) is sufficiently high to lead to the action—possibly of a violent or dangerous character—which is the habitual outcome of the belief. But since the belief is implanted by the deliberately false or arbitrary suggestion of an experimenter (so-called 'operator'), or by the accidental influence of some sight, sound, smell, or touch upon the brain of an individual who has 'fallen' (as we all do more or less at times) into the condition like that of sleep-walking—with the reasoning faculty in abeyance—the actions of such persons appear astonishing and ludicrous to onlookers. Thus we see that the intensity of a belief is no measure of the probability of its truth, and that there are exceptional or unhealthy conditions of the brain in which preposterous beliefs may become implanted in men who are usually capable of sound thought, and even of scientific discovery.

"When we appreciate the fact that a 'belief' is a state of mind which may be produced by the thorough application of the scientific method, or, on the other hand, by hypnotism, it becomes obvious that we cannot logically contrast 'scientific knowledge' and 'belief.' The word 'belief' is often used to signify 'mere belief,' or 'empty belief,' or 'fanciful belief,' which is not based on experiment and verification. When some one says, 'I *believe* that this is so-and-so,' it is necessary, if we are to apprehend his state of mind, that he should state the evidence on which his 'belief' is founded and the degree of probability which exists that the belief is a correct interpretation of the

evidence. Moreover, it is the fact that there is as great need to look into the meaning of the word 'knowledge' and what we 'know' as there is to be careful about what we mean by a 'belief.' What can we 'know' of what we call 'matter,' or of what we call 'mind'? The answer is, so far as the ultimate nature of either is concerned, 'Nothing!'"

NOTE M.—Professor Baker, by purifying hydrogen and oxygen to a point not previously attained, has discovered that the combination of these gases is delayed under all conditions, even those which determine instantaneous combination of mixtures of the two gases not previously brought to this high degree of purity. We have here the suggestion that a "catalyzing" impurity may not be merely an accelerator, but a necessary adjuvant for chemical combination in many cases where the rapid occurrence of combination is usually ascribed to supposed "great" or urgent affinity.

NOTE N.—The statement by Faraday that a man "has no right" to make a statement and to declare that it is the duty of others to prove him right or wrong, is, perhaps, open to misinterpretation. It is difficult to show that a man "has no right"—putting it in that bald, unqualified way—to say or to do many things which according to the circumstances and occasion may be or may not be deserving of condemnation. In the case which Faraday is considering that of the assertor of a new thing who demands an answer in the form of "Yes" or "No" to his assertion—the fact is that he has a perfect "right" as a "citizen of a free country" to make a foolish demand, compliance with which he cannot enforce. Supposing that at the same time he claims to be judged as a reasonable being—it is clear that "he has no right," as such, to conclude that his assertion is correct or in any way verified by the refusal or even the inability of the person or persons addressed by him to give him the answer "Yes" or "No." Nor have interested bystanders, if claiming to be guided by reason, the right to conclude that his assertion is correct because no one undertakes to show that it is incorrect. That method of "forcing a conclusion" is rarely admitted even in a court of law or a friendly debate. Yet it is true to-day as it was sixty years ago, that the wonder-monger and the scaremonger are encouraged to make fantastic statements and to demand that they shall be either accepted as true or else shown to be false, because a large portion of the public is habitually unreasonable and prefers the emotional excitement accompanying credulity to the suspension of judgment and the ultimate certainty proper to the exercise of reason. The education of the youth of all classes in the methods and results of the natural sciences, as advocated in these lectures, is the only cure for the dangerous, and possibly disastrous state of irrationality which still prevails in the most highly civilized communities.

NOTE O.—Faraday does not here refer to photographs in colours - such as are obtained by the Lumière process, invented long after his death, but to the reproduction of the varied colours of natural scenes and objects by corresponding variations of paler or darker tint in the photographer's monotone pictures.

NOTE P.—The number of metals at present known to chemists has been increased from the fifty known in 1854 to sixty-three. In addition to these metals, eighteen non metallic elements are known at the present day (1916).

NOTE Q.—The "state of the subject" revealed by the clergyman's note in 1854 persists to a very large extent at the present moment. There are to-day but few clergymen or other persons who have "enjoyed" a university education who are competent to deal with the preposterous statements in regard to "occultism" and such pretended "wonders" which are constantly in circulation. The ignorance of the well-to-do class and the readiness of newspaper editors to enliven their columns with baseless gossip, and of newspaper readers to feed their minds with it, still lead to the propagation of such false reports as that cited by Faraday's correspondent. E. RAY LANKESTER.

ON THE IMPORTANCE OF THE STUDY OF LANGUAGE AS A BRANCH OF EDUCATION FOR ALL CLASSES

A LECTURE DELIVERED AT THE ROYAL INSTITUTION OF GREAT BRITAIN

By ROBERT GORDON LATHAM, M.D., F.R.S.

The subject I have the honour of illustrating is "The Importance of the Study of Language as a means of Education for all Classes."

I open it by drawing a distinction.

A little consideration will show that that difference between the study of a given subject in its general and abstract and the study of one in its applied or concrete form, which finds place in so many departments of human knowledge, finds place in respect to Language and Languages. It finds place in the subject before us as truly as it does in that science which one of my able successors will have the honour of illustrating—the science of the laws of Life—Physiology or Biology. Just as there is therein a certain series of laws relating to life and organization, which would command our attention if the whole animal and vegetable world consisted of but a single species, so the study of Speech would find place in a well-devised system of education, even if the tongues of the whole wide world were reduced to a single language, and that language to a single dialect. This is because the science of life is one thing, the science of the forms under which the phenomena of life are manifested, another. And just as Physiology, or Biology, is, more or less, anterior to and independent of such departments of study as Botany and Zoology, so, in the subject under notice, there is the double division of the study of *Language* in respect to structure and development, and the study of *Languages* as

instances of the variety of form in which the phenomenon of human speech exhibits, or has exhibited, itself. Thus—

When (as I believe once to have been the case) there was but a single language on the face of the earth, the former of these divisions had its subject-matter. And—

When (as is by no means improbable) one paramount and exclusive tongue, developed, at first, rapidly and at the expense of the smaller languages of the world, and, subsequently, slowly and at that of the more widely diffused ones, shall have replaced the still numerous tongues of the nineteenth century; and when all the dialects of the world shall be merged into one Universal Language, the same subject-matter for the study of the structure of Language, its growth and changes, will still exist.

So that the study of Language is one thing, the study of Languages, another.

They are different; and the intellectual powers that they require and exercise are different also. The greatest comparative philologists have, generally, been but moderate linguists.

A certain familiarity with different languages they have, of course, had; and as compared with that of the special scholar —the Classic or the Orientalist, for instance—their range of language (so to say) has been a wide one; but it has rarely been of that vast compass which is found in men after the fashion of Mezzofanti, etc.—men who have spoken languages by the dozen, or the score;—but who have left comparative philology as little advanced as if their learning had been bounded by the limits of their own mother tongue.

Now this difference, always of more or less importance in itself, increases when we consider Language as an object of education; and it is for the sake of illustrating it that the foregoing preliminaries have been introduced. No opinion is given as to the comparative rank or dignity of the two studies; no decision upon the nobility or ignobility of the faculties involved in the attainment of excellence in either. The illustration of a difference is all that has been aimed at. There is a difference between the two classes of subjects, and a difference between the two kinds of mental faculties. Let us make this difference clear. Let us also give it prominence and importance.

One main distinction between the study of Language and the study of Languages lies in the fact of the value of the former being *constant*, that of the latter, *fluctuating*. The relative importance of any two languages, as objects of special attention, scarcely ever remains steady. The value, for instance, of the German—to look amongst the contemporary forms of speech—has notably risen within the present century. And why? Because the literature in which it is embodied has improved. Because the scientific knowledge which, to all who want the key, is (so to say) locked up in it, has increased some hundred per cent.

But it may go down again. Suppose, for instance, that new writers of pre-eminent merit ennoble some of the minor languages of Europe—the Danish, Swedish, Dutch, etc. Such a fact would divide the attention of *savants*—attention which can only be bestowed upon some second, at the expense of some first, object. In such a case, the extent to which the German language got studied would be affected much in the same way as that of the French was by the development of the literature of Germany.

Or the area over which a language is spoken may increase; as it may, also, diminish.

Or the number of individuals that speak it may multiply—the area being the same.

Or the special application of the language, whether for the purposes of commerce, literature, science, or politics, may become changed. In this way, as well as in others, the English is becoming, day by day, more important.

There are other influences.

High as is the value of the great classical languages of Greece and Rome, we can easily conceive how that value might be enhanced. Let a manuscript containing the works of some of the lost, or imperfectly preserved, writers of antiquity be discovered. Let, for instance, Gibbon's *desiderata*—the lost *Decads of Livy*, the *Orations of Hyperides*, or the *Dramas of Menander*—be made good: the percentage of classical scholars would increase; little or much.

Some years back it was announced that the *Armenian* language contained translations, made during the earlier centuries of our era, of certain classical and ecclesiastical

writings, of which the originals had been lost—lost in the interval. This did not exactly make the Armenian, with its alphabet of six-and-thirty letters, a popular tongue; but it made it, by a fraction, more popular than it was in the days of Whiston and La Croze when those two alone, of all the learned men of Europe, could read it.

Translations tell in another way. Whatever is worth reading in the Danish and Swedish is forthwith translated into German. E.g. Professor Retzius of Stockholm wrote a good *Manual of Anatomy*. He had the satisfaction of seeing it translated into German. He had the further satisfaction of hearing that the translation ran through five editions in less time than the original did through one.

Now, if the Germans were to leave off translating, the value of the language in which Professor Retzius wrote his Anatomy would rise.

Upon the whole, the French is, perhaps, the most important language of the nineteenth century; yet it is only where we take into consideration the whole of its elements of value. To certain special *savants*, the German is worth more; to the artist, the Italian; to the American, the Spanish. It fell, too, in value because it became less indispensable; and another cause, now in operation, affects the same element of indispensability. The French are beginning to learn the languages of other nations. Their own literature will certainly be none the worse for their so doing. But it by no means follows that that literature will be any the more studied; on the contrary, Frenchmen will learn English more, and, *pro tanto*, Englishmen learn French less.

If all this has illustrated a difference, it may also have done something more. It may have given a rough sketch, in the way of classification, of the kind of facts that regulate the value of special languages as special objects of study. At any rate (and this is the main point), the subject-matter of the present Address is narrowed. It is narrowed (in the first instance at least) to the consideration of that branch of study whereof the value is constant; for assuredly it is this which will command more than a moiety of our consideration.

This may be said to imply a preference to the study of Language as opposed to that of Languages—a *singular* prefer-

ence, as a grammarian may, perhaps, be allowed to call it. It cannot be denied that, to a certain extent, such is the case; but it is only so to a certain extent. The one is not magnified at the expense of the other. When all has been said that logic or mental philosophy can say about the high value of comparative philology, general grammar, and the like, the lowest value of the least important language will still stand high, and pre-eminently high that of what may be called the *noble* Languages. No variations in the philological barometer, no fluctuations in the Exchange of Language, will ever bring down the advantage of studying one, two, or even more foreign languages to so low a level as to expel such tongues as the Latin, the Greek, the French, or the German, one and all, from an English *curriculum* —and *vice versa*, English from a foreign one.

Now, if this be the case, one of the elements in the value of the *study of Language* in general will be the extent to which it facilitates the acquirement of any one language in particular, and this element of value will be an important—though not the most important—one.

The structure of the human body is worth knowing, even if the investigator of it be neither a practitioner in medicine nor a teacher of anatomy; and, in like manner, the structure of the human language is an important study irrespective of the particular forms of speech whereof it may facilitate the acquirement.

The words on the diagram-board will now be explained. They are meant to illustrate the class of facts that comparative philology supplies. The first runs—

KLEIN : CLEAN :: PETIT : PETITUS.

It shows the extent to which certain ideas are associated. It shows, too, something more; it shows that such an association is capable of being demonstrated from the phenomena of language instead of being a mere *à priori* speculation on the part of the mental philosopher.

Klein is the German for *little*; *clean* is our own English adjective, the English of the Latin word *mundus*. In German the word is *rein*.

Now, notwithstanding the difference of meaning in the two tongues, *clean* and *klein* are one and the samé word. Yet, how are the ideas of *cleanliness* and *littleness* connected? The

Greek language has the word *hypocorisma*, meaning a *term of endearment*, and the adjective *hypocoristic*. Now, *clean-ness*, or *neat-ness*, is one of the elements that make *hypocoristic* terms (or terms of endearment) applicable. And so is *smallness*. We talk of *pretty little dears*, a thousand times, where we talk of *pretty big dears* once. This, then, explains the connexion; this tells us that *clean* in English is *klein* in German, word for word.

You doubt it, perhaps. You shake your head, and say that the connexion seems somewhat indefinite; that it is just one of those points which can neither be proved nor disproved. Be it so. The evidence can be amended. Observe the words *petit* and *petitus*. *Petit* (in French) is exactly what *klein* is in German, i.e. *little*. *Petitus* (in Latin) is very nearly what *clean* is in English, i.e. *desired*, or *desirable*. That *petit* comes from *petitus* is undeniable.

Hence, where the German mode of thought connects the ideas of *smallness* and *cleanness*, the Latin connects those of *smallness* and *desirability;* so that as *petit* is to *petitus*, so is *klein* to *clean*. In the diagram this is given in the formula of a sum in the Rule of Three.

The words just noticed explain the connexion of ideas in the case of separate words. The forthcoming help us in a much more difficult investigation. What is the import of such sounds as that of the letter *s* in the word father-*s*? It is the sign of the plural number.

Such is the question—such the answer; question and answer connected in the word *fathers* solely for the sake of illustration. Any other word, and any other sign of case, number, person, or tense, would have done as well.

But *is* the answer a real one? Is it an answer at all? How come such things as plural numbers, and signs of plural numbers, into language? How the particular plural before us came into being, I cannot say; but I can show how *some* plurals have. Let us explain the following—

NGI = I.	NGI-N-DE = WE.
NGO = THOU.	NGO-N-DA = YE.
NGU = HE.	NGE-N-DA = THEY.

DA = WITH.

ME - CUM = ME.

The *da* (or *de*) in the second column, is the sign of the plural number in a language which shall at present be nameless. It is also the preposition *with*. Now *with* denotes *association;* association *plurality*. Hence

Ngi - n - de = I + = *we*.
Ngo - n - da = thou + = *ye*.
Nge - n - da = he + = *they*.

This is just as if the Latins, instead of *nos* and *vos*, said *me-cum* and *te-cum*.

Such is the history of one mode of expressing the idea of plurality; we can scarcely say of a *plural number*. The words *plural number* suggest the idea of a single word, like *fathers*, where the *s* is inseparably connected with the root, at least so far inseparably connected as to have no independent existence of its own. *Ngi-n-de*, however, is no single word at all, but a pair of words in juxtaposition, each with a separate existence of its own. But what if this juxtaposition grow into *amalgamation?* What if the form in *da* change? What if it become *t* or *z*, or *th*, or *s*? What if, meanwhile, the separate preposition *da* change in form also; in form or meaning, or, perhaps, in both? In such a case a true plural form is evolved, the history of its evolution being a mystery.

So much for one of the inflections of a *noun*. The remaining words illustrate one of a *verb*.

Hundreds of grammarians have suggested that the signs of the *persons* in the verb might be neither more nor less than the personal pronouns *appended*, in the first instance, to the verb, but afterwards amalgamated or incorporated with it. If so, the *-m* in *inqua-m*, is the *m* in *me*, etc. The late Mr. Garnett, a comparative philologist whose reputation is far below his merits, saw that this was not exactly the case. He observed that the appended pronoun was not so much the *Personal* as the *Possessive* one: that the analysis of a word like *inqua-m* was not so much, *say* + *I*, as *saying* + *my;* in short, that the verb was a noun, and the pronoun either an adjective (like *meus*) or an oblique case (like *mei*), agreeing with, or governed by, it.

It is *certainly* so in the words before you. In a language, which, at present, shall be nameless, instead of saying *my*

apple, thy apple, they say what is equivalent to *apple-m, apple-th*, etc.; i.e. they append the possessive pronoun to the substantive, and by modifying its form, partially incorporate or amalgamate it. They do more than this. They do (as the diagram shows us) precisely the same with the verbs in their *personal* as they do with the nouns in their *possessive* relations. Hence, *olvas-om*, etc., is less *I read* than *my-reading;* less *read* + *I*, than *reading* + *my*.

1

OLVAS—OM = I READ.
OD = THOU READEST.
UK = WE READ.
ATOK = YE READ.

2

ALMA—M = MY APPLE.
D = THY APPLE.
NK = OUR APPLE.
TOK = YOUR APPLE.

I submit that facts of this kind are of some value, great or small. But the facts themselves are not all. How were they got at? They were got at by dealing with the phenomena of language as we found them, by an induction of no ordinary width and compass; and many forms of speech had to be investigated before the facts came out in their best and most satisfactory form.

The illustration of the verb (*olvasom*, and *almam*, etc.) is from the Hungarian; that of the plural number (*nginde*, etc.), from the Tumali—the Tumali being a language no nearer than the negro districts to the south of Kordovan, between Sennaar and Darfur, and (as such) not exactly in the highway of literature and philology.

Now I ask whether there be, or whether there be not, certain branches of inquiry which are, at one and the same time, recognized to be of the highest importance, and yet not even remarkable for either unanimity of opinion, precision of language, or distinctness of idea on the part of their professors.

I ask whether what is called, with average clearness, Mental Philosophy, and, with somewhat less clearness, Metaphysics, be not in this predicament? I ask whether, in this branch of investigation, the subject-matter do not eminently desiderate something definite, palpable, and objective, and whether these same desiderated tangibilities be not found in the wide field of Language to an extent which no other field supplies? Let this field be a training-ground. The facts it gives are of value. The method it requires is of value.

As the languages of the world, the forms of speech mutually unintelligible, are counted by the hundred, and the dialects by the thousand, the field is a large one—one supplying much exercise, work, and labour. But the applications of the results obtained are wide also; for, as long as any form of mental philosophy remains susceptible of improvement, as long as its improved form remains undiffused, so long will a knowledge of the structure of language in general, a knowledge of comparative philology, a knowledge of general grammar (for we may choose our term), have its use and application. And, assuredly, this will be for some time.

As to its special value in the particular department of the ethnologist, high as it is, I say nothing, or next to nothing, about it; concerning myself only with its more general applications.

Let it be said, then, that the study of language is eminently disciplinal to those faculties that are tasked in the investigation of the phenomena of the human mind; the value of a knowledge of these being a matter foreign to the present dissertation, but being by no means low. High or low, however, it measures that of the studies under notice.

But how is this general philology to be taught? Are youths to seek for roots and processes in such languages as the Hungarian and the Tumali? No. The teaching must be by means of well-selected suggestive examples, whereby the student may rise from particulars to generals, and be taught to infer the uncertain from the certain. I do not say that the *s* in *fathers* arose exactly after the fashion of the Tumali plural; but, assuredly, its development was the same in kind, if not in detail. At all events, language must be dealt with as a *growth*.

In the first stage of speech, there are no inflections at all,

separate words serving instead of them: just as if, instead of saying *fathers*, we said *father many*, or *father father*; reduplication being one of the makeshifts (so to say) of this period. The languages allied to the Chinese belong to this class.

In the second stage, the separate words coalesce, but not so perfectly as to disfigure their originally separate character. The Hungarian persons have illustrated this. Language now becomes what is called *agglutinate*. The parts cohere, but the cohesion is imperfect. The majority of languages are agglutinate.

The Latin and Greek tongues illustrate the third stage. The parts originally separate, then agglutinate, now become so modified by contact as to look like secondary parts of a single word; these original separate substantive characters being a matter of inference rather than a patent and transparent fact. The *s* in *fathers* (which is also the *s* in *patre-s* and *πάτερε-ς*) is in this predicament.

Lastly, inflections are replaced by prepositions and auxiliary verbs, as is the case in the Italian and French when compared with the Latin.

Truly, then, may we say that the phenomena of speech are the phenomena of growth, evolution, or development; and as such must they be taught. A cell that grows—not a crystal that is built up—such is language.

But these well-devised selections of suggestive examples, whereby the student may rise from particulars to generals, etc., is not to be found in the ordinary grammars. Indeed, it is the very reverse of the present system; where there are twenty appeals to the memory in the shape of what is called a *rule*, for one appeal to the understanding in the shape of an illustrated process. So much the worse for the existing methods.

Moulds applied to growing trees—cookery-book recipes for making a natural juice—these are the parallels to the artificial systems of grammar *in their worst forms*. The *better* can be excused, sometimes recommended; even as the Linnæan system of botanical teaching can, in certain cases, be used with safety, *provided always that its artificial character be explained beforehand, and insisted on throughout.*

To stand on the level of the Linnæan system, an artificial grammar must come under the following condition: *It must*

leave the student nothing to unlearn when he comes to a natural one.

How can this be done? It can be done, if the grammarian will be content to teach *forms* only, leaving processes alone. Let him say (for instance) that the Latin for:

I call is *voc*-o.
Thou callest, *voc*-as.
Calling, *voc*-ans.
I called, *voc*-avi, etc.

But do not let him say that active aorists are formed from futures, and passive ones from the third person singular of the perfect. His forms, his paradigms, will be right; his rules, in nine cases out of ten, wrong. I am satisfied that languages can be taught without rules, and by paradigms only.

This recognition of what has been called *artificial* grammar for the teaching of special languages, as opposed to the general grammar of the comparative philologist, should serve to anticipate an objection. "Would you," it may be asked, "leave the details of languages like the Latin, Greek, French, German, etc.—languages of eminent practical utility—untaught until such time as the student shall have dipped into Chinese, touched upon Hungarian, and taken a general idea of the third stage from the Latin, and of the fourth from the French? If so, the period of life when the memory for words is strongest will have passed away before any language but his own mother-tongue has been acquired."

The recognition of such a thing as artificial grammar answers this in the negative. If a special language be wanted, let it be taught betimes: only if it cannot be taught in the most scientific manner, let it be taught in a manner as little unscientific as possible.

In this lies an argument against the ordinary teaching (I speak as an Englishman) of English. What do we learn by it?

In the ordinary teaching of what is called the grammar of the English language there are two elements. There is something professed to be taught which is not, but which, if taught, would be worth learning; and there is something which, from being already learned better than any man can teach it, requires

no lessons. The one (the latter) is the use and practice of the English tongue. This the Englishman has already. The other is the principles of grammar. With existing text-books this is an impossibility. What then *is* taught? Something (I am quoting from what I have written elsewhere) undoubtedly. The facts that language is more or less regular; that there *is* such a thing as grammar; that certain expressions should be avoided, are all matters worth knowing. And they are all taught even by the worst method of teaching. But are these the proper objects of *systematic* teaching? Is the importance of their acquisition equivalent to the time, the trouble, and the displacement of more valuable subjects which are involved in their explanation? I think not. Gross vulgarity of language is a fault to be prevented; but the proper prevention is to be got from habit—not rules. The proprieties of the English language are to be learned, like the proprieties of English manners, by conversation and intercourse; and a proper school for both is the best society in which the learner is placed. If this be good, systematic teaching is superfluous; if bad, insufficient. There *are* undoubted points where a young person may doubt as to the grammatical propriety of a certain expression. In this case let him ask some one older and more instructed. Grammar, as an *art*, is, undoubtedly, *the art of speaking and writing correctly*—but then, as an *art*, it is only required for *foreign* languages. For our *own* we have the necessary practice and familiarity.

The true claim of English grammar to form part and parcel of an English education stands or falls with the value of the philological knowledge to which grammatical studies may serve as an introduction, and with the value of scientific grammar as a *disciplinal* study. I have no fear of being supposed to undervalue its importance in this respect. Indeed, in assuming that it is very great, I also assume that wherever grammar is studied as grammar, the language which the grammar so studied should represent must be the mother-tongue of the student; *whatever that mother-tongue may be*—English for Englishmen, Welsh for Welshmen, French for Frenchmen, German for Germans, etc. This study is the study of a theory; and for this reason it should be complicated as little as possible by points of practice. For this reason a man's mother-tongue is the best medium for

the elements of scientific philology, simply because it is the one which he knows best in practice.

Limit, then, the teaching of English, except so far as it is preparatory to the study of language in general; with which view, teach as scientifically as possible.

Go further. Except in special cases, limit the teaching of the classical tongues to one out of the two. *One*, for all *disciplinal* purposes, is enough. In this, go far. Dead though the tongue be, and object of ridicule as the occupation is becoming, go to the length of writing verses, though only in a few commoner metres. Go far, and go in one direction only. There are reasons for this singleness of path. I fear that there is almost a necessity. As long as men believed that the ordinary Latin and Greek grammars were good things of themselves, and that, even if they did not carry the student far into the classics, they told him something of value respecting language in general, a *little learning* in the dead languages was a good thing. But what if the grammars are *not* good things? What if they are absolutely bad? In such a case, the classical tongues cease to be learnt except for themselves. Now, one of the few things that is more useless than a little Latin is a little Greek.

Am I wrong in saying that, with nine out of ten who learn *both* Latin and Greek, the knowledge of the two tongues conjointly is not greater than the knowledge of one of them singly ought to be?

Am I wrong in believing that the tendencies of the age are in favour of decreasing rather than increasing the amount of time bestowed upon classical scholarship?

Unless I be so, the necessity for a limitation is apparent.

To curtail English—to eliminate one of the classical tongues—possibly that of Pericles, at any rate, either that of Pericles or of Cicero—to substitute for the ordinary elements of a so-called classical education illustrations from the Chinese, the Hungarian, or the Tumali—this is what I have recommended.

I cannot but feel that in so doing I may seem to some to have been false to my text, which was to eulogize things philological. They may say, *Call you this backing your friends?* I do. It is not by glorifying one's own more peculiar studies that such studies gain credit. To show the permanent, rather

than the accidental, elements of their value, is the best service that can be done for them. It is also good service to show that they can be taught with a less expenditure of time and labour than is usually bestowed on them. But the best service of all is to indicate their disciplinal value ; and to show that, instead of displacing other branches of knowledge, they so exercise certain faculties of the mind as to prepare the way to them.

ON THE IMPORTANCE OF THE STUDY OF CHEMISTRY AS A BRANCH OF EDUCATION FOR ALL CLASSES

A LECTURE DELIVERED AT THE ROYAL INSTITUTION OF GREAT BRITAIN

By CHARLES G. B. DAUBENY, M.D., F.R.S.
Professor of Chemistry and of Botany in the University of Oxford

I CAN imagine one of the regular frequenters of this theatre, who had caught the first part only of the title which announces the Lecture I am about to deliver, marvelling not a little that your managers should have thought it worth their while to invite a professor from Oxford to indoctrinate the members of the Royal Institution with respect to the "Importance of Chemistry."

That arguments for such a purpose might be useful in the provinces, or even to an academic body occupied for the most part on the literature of past ages, would appear but natural; but that any considerations of the kind should be pressed upon the attention of those who are in the daily habit of watching the unfolding of those scientific truths of which this Institution may be said to be the birthplace, might seem to them little better than an unprofitable waste of time.

I must, therefore, begin by reminding you that the subject of this Lecture is not the importance of chemistry, considered in itself, but only as it is an instrument of general education; and, in this point of view, it appears to me that the very circumstance which may to some appear to render such a discussion here superfluous, imparts to it a peculiar propriety, when we regard the place in which it is delivered, and the audience I am now addressing.

Education, gentlemen, I need hardly say, is framed with

reference to the requirements of the great mass of society, rather than of that small number of individuals who are capable of rising to eminence. Genius under any circumstances, and despite of almost every amount of discouragement, will carve for itself a path to distinction: it grows up under the most dissimilar modes of mental culture; and is capable of extracting nourishment, for its own development, from the hardest and most indigestible food.

But it is for the sake of those not intended by nature as the pioneers of discovery, or as the originators of new principles in science, that our systems of education are chiefly framed; and such men would be rather deterred from the study than invited to it, by having put before them so frequently, as is the case within this theatre, the results of those original and profound investigations which have signalized the march of modern chemistry.

In consequence of having their attention riveted upon points of scientific research, which are placed on heights to them inaccessible, they are the more likely to overlook the harvest that lay at their very feet, and which came within the compass of those powers and energies of mind, which fall to the common lot of mankind.

It will therefore be my purpose to show, that even to those who do not feel within themselves the capacity of originating new truths, or even of fully apprehending the higher problems with which this science has to grapple, chemistry is a study, not only of lively interest, but also of great utility, with a view to attaining those objects which are aimed at in every complete and well-digested scheme of national education.

And in employing the term "national education," I mean to include in it that of the highest as well as of the humblest grade of society; for although the difference is great indeed between the completeness of the instruction provided, and consequently between the machinery employed, in these two cases, I can recognize no fundamental difference in the objects aimed at.

Primary education, I conceive, independently of the reference it ought to have to the inculcation of right principles in religion and morality, objects which, although the most important of any, do not fall within the scope of this lecture—has two distinct ends to accomplish: namely, first, that of disciplining and

developing the several powers of the mind; and, secondly, that of imparting to it certain kinds of useful general information.

Although some have insisted exclusively upon the former, whilst others have attached the greatest weight to the latter of these objects, it is certain that they can neither be disjoined in practice, nor ought to be separated in theory, by any judicious system of education. With the exception perhaps of logic and pure mathematics there are none of the sciences which do not at once supply materials for thought and reflection, as well as improve the faculty of apprehending and comparing them; nor, on the other hand, would it be easy to pitch upon any species of knowledge worthy of a place in a system of liberal instruction which does not also, to a certain extent, exercise and discipline the understanding.

This, however, supplies no reason why we should not keep distinct in theory the two ends above mentioned, and consider separately the best means by which each may be attained—and first, then, beginning with that which we regard as the more important of the two, let us consider what kind of education is likely to operate most effectually in disciplining and developing the mental organization.

The intellectual principle in man is in its early state scarcely to be distinguished from the instinct of brutes, and is in some respects inferior to it; but it yet contains within itself the capacity of reasoning, of imagination, of taste, of tracing resemblances, and thus of classifying the objects presented before it—the germs, in short, of all the powers and endowments which we find afterwards unfolded. In whatever degree these gifts may in each instance be apportioned, it is hardly possible to conceive a rational being totally destitute of any one of them; incapable, that is, either of deducing inferences from the facts before him, of combining the images presented to his mind by the senses into new forms, of being pleasurably affected by certain arrangements of ideas more than by others, or of placing together individual facts in some sort of order or method.

Now, it is the primary object of education to impart to each of these faculties its proper development, and no system which overlooks any one of them can be regarded as complete. Any method which should mature the judgment without calling into play the inventive faculty, or which cultivated the taste, to the

neglect of the powers of classifying, combining, or reasoning upon the objects brought before the mind, must be condemned as defective.

Now it will be my endeavour to show that the study of chemistry is conducive to more than one of the great ends above pointed out as the general aim of Education.

It has been objected to, indeed, that its principles are as yet not sufficiently defined, or susceptible of that degree of mathematical precision which befits them for the purpose of training the powers of reasoning.

Nor would I by any means desire that by those who have the leisure and ability to pursue to any extent the study of mathematics, chemistry should be admitted as a substitute.

Whilst, however, there are many in every class of society, even, indeed, in the highest, upon whose minds abstract propositions scarcely take any hold; there are probably none who would not reap advantage from having their attention directed to a class of subjects upon which the premises are presented to them in a more palpable form, and the conclusions to be deduced are of that contingent character which bear a nearer analogy to those relating to the ordinary events of man's life.

But the cultivation of the reasoning powers constitutes only a part, and even the smallest part, of the services rendered by chemistry in the cultivation of the intellect. No one of the physical sciences, perhaps, is equally well calculated to promote habits of close observation; a rigorous attention to all the peculiarities of each phenomenon; that aptitude in forming new combinations out of the impressions received from without, which constitutes imagination and gives birth to invention; and that power of detecting similitudes and differences which enables the mind to arrange and classify in some sort of order the diversified objects presented to it.

Nor is this so common an endowment as might be at first supposed. "One man," says Mr. Mill, "from inattention, or attending only in the wrong place, overlooks half of what he sees; another sets down much more than he sees, confounding it with what he imagines, or with what he infers; another takes note of the kind of all the circumstances, but being inexpert in estimating their degree, leaves the quantity of each vague and uncertain; another sees, indeed, the whole, but

makes such an awkward division of it into parts, throwing things into one mass which requires to be separated, and separating others which might more conveniently be considered as one, that the result is much the same, sometimes even worse, than if no analysis had been attempted at all.

"To point out what qualities of mind or modes of mental culture fit a man for being a good observer is a question which belongs to the theory of education. There are rules of self-culture which render us *capable of observing*, as there are arts for *strengthening the limbs*." *

In ascribing to the study of this science all these several advantages, I am not, of course, considering it as if it were to be prosecuted exclusively from books, or consisted in the mere committal to memory of a certain number of facts and principles. The student who embarks with any degree of zeal or ardour in this branch of philosophy is almost irresistibly led on from theory to experiment, and becomes impelled by mere curiosity, if not by some higher motive, to observe with his own eyes, and to verify by his own senses, those properties of matter which verbal description can, after all, only faintly and imperfectly delineate.

Once entered upon this line of pursuit, he engages in it with something of the same zest which the sportsman entertains in tracking his game—he soon begins to experience a personal pride in the success of his trials, and feels himself humbled in his own estimation, if they should chance to disappoint his anticipations.

There is also always enough of uncertainty with respect to the success of an experiment, especially in unpractised hands, to keep awake his attention, and to bring the subject, as respects himself, under the category of contingent events.

Every chemist, indeed, soon becomes aware on how many minute and apparently unimportant points the success of any of his processes depends, and how much incidental knowledge of other bodies, besides those upon which he is operating, becomes requisite, in order to guard against defeat.

The student, also, after following for some time in the footsteps of others, and satisfying himself by ocular proof of the

* Mill's *Logic*, vol. i, p. 438.

facts which first attracted his curiosity, is led on to question Nature himself for further information, and to engage in independent lines of research, which will, to a certain extent at least, partake of the character of originality.

And here the inventive faculty is at once disciplined and excited; for whilst his imagination is checked in its random flights by the penalty of failure imposed upon unsound and visionary speculation, his power of combining into new arrangements the ideas presented to his mind is promoted, by the necessity of contriving new processes, and of meditating upon what is likely to occur under another set of conditions.

Illustrations of this will occur during every attempt at analysis, during the examination of every new substance submitted to the chemist.

In each case the solution of the problem can only be arrived at by a number of tentative efforts, each of which requires, on the part of the operator, the exercise of invention, of memory, and of judgment.

Simple as the principle elicited may appear to be, when the key to its solution has been found, often, indeed, the more simple in proportion to the elevated rank it holds amongst the truths of the science, the discoverer alone knows through how many devious paths of error the clue to its attainment had to be followed, and how much his own intellectual vigour was, in the meantime, promoted by the pursuit.

Let me remind you, for instance, of that important yet simple law which established the connexion between electrical attraction and chemical affinity, the investigation of which led the illustrious individual who first gave celebrity to this institution to some of the greatest discoveries of modern chemistry.

We are at present so familiarized with the fact that water is resolved by voltaic electricity into oxygen and hydrogen gases alone, as to be scarcely able to estimate the difficulties that beset the earlier experimentalists, or to account for the number of conflicting hypotheses suggested for a phenomenon now considered as so simple.

Nevertheless, when Davy first turned his attention to the subject, the constant association of acid with the oxygen, and of alkali, and even lime, with the hydrogen of the water decom-

posed, complicated the phenomenon in such a manner that it was difficult to arrive at any satisfactory explanation of it.

It required, perhaps, no particular sagacity to conjecture that these foreign ingredients might be derived from the vessels, or other bodies, in contact with the electrolyzed water, but the difficulty consisted in demonstrating that such was the case. Davy was soon led by this suspicion to discontinue the use of vegetable or animal substances for connecting the poles, finding that all such materials yielded, by their decomposition, muriatic acid ; and, for the same reason, he also abandoned glass vessels, as yielding soda.

By substituting, therefore, agate for glass, and fibres of pure amianthus for cotton, he had reason to flatter himself that every source of fallacy had been removed ; but to his surprise, muriatic acid still made its appearance at the positive pole, and soda at the negative.

Here a fanciful or an indolent operator might have been tempted to stop ; for at that period it was regarded by no means so self-evident as it may appear to us at present that such bodies as alkalies and acids might not be generated by an agent of which so little was known, and from whose mysterious operation everything might be expected.

Davy, however, was not to be diverted from his inquiries by any such visionary speculations. By ascertaining that the quantity of saline matter diminished when the experiments were again and again repeated, he felt justified in concluding that the agate must have yielded it. Still, however, a constant, although a smaller quantity of alkali was generated in each experiment ; and to determine its source, cups of pure gold were substituted for those of agate. Yet, even then, the same alkali was obtained, and as the only other conceivable source was the water, this, though it had been already carefully distilled, was submitted to analysis, and found to contain in the quart seven-tenths of a grain of saline matter.

Davy now fancied that he should cut off every remaining source of error by re-distilling the water in silver vessels, with the most scrupulous care. The water was thus obtained in a state of absolute purity, but still the alkali, although diminished in quantity, did not altogether disappear when the water was electrolyzed. Upon a more critical examination, however,

it turned out that the alkali thus generated was no longer soda, but ammonia.

It thus appeared that even when every apparent means of impurity had been removed, alkaline matter was evolved during the electrolyzation of water; and the same conclusion seemed deducible with respect to the other extraneous product, which, however, now that all vegetable matter had been excluded, was found to consist, not as before of muriatic, but of nitric acid.

If then occurred to Davy's sagacious mind that both these products might have arisen from the affinity of the nitrogen of the surrounding air, for the oxygen of the water on the one hand, and for its hydrogen on the other.

He therefore next performed the experiment under an exhausted receiver, employing for the purpose of electrolyzation water deprived of air by careful boiling. His method succeeded at least in cutting off the supply of ammonia, and thus satisfied him that he had hit upon the real cause of its previous occurrence.

But a difficulty still remained to be got over; for even under these circumstances nitric acid continued to be present, although in much smaller quantities than before.

The crowning experiment therefore had still to be achieved; the receiver under which the voltaic action was to take place, after being exhausted, was carefully filled with hydrogen, and then a second time exhausted, so as to secure the entire exclusion of atmospheric air.

When this final step was taken, the operator had at length the satisfaction of finding that all sources of fallacy were removed, neither acid nor alkali being generated, even when the voltaic process had been continued during twenty-four hours; thus justifying him in laying down, as now beyond the reach of doubt, that nothing but hydrogen and oxygen is produced by the decomposition of pure water.

I have been the more disposed to dwell upon this particular train of research because it seems to me to place the philosophical character of Sir Humphry Davy under rather a different aspect than that in which superficial observers are wont to regard it: exhibiting him, not as the individual who

by the sudden inspiration of his genius lighted at once upon those brilliant discoveries which changed the face of the science ; but as one who, by a long and laborious train of research, succeeded in realizing the vision which his sagacious intellect had, in the first instance, dimly conceived.

If we regard, as the two most important services rendered by this great philosopher to his favourite science, the discovery of the alkaline and earthy Bases, and the correction of our views with respect to the nature of Chlorine—the former as being his greatest contribution to the facts of chemistry, the latter to its logic—we shall find that in both instances the results were arrived at by much patient inquiry, many minute and apparently trivial manipulations, and a tenacity of purpose not to be turned aside by the difficulties which everywhere beset his path.

And it is well for the student thus to obtain a timely warning that such is the general case with genius, not merely when occupied in the walks of science, but also in every other branch of mental exertion—exemplified equally in a Davy and a Liebig, as in a Fox and a Sheridan ; for that by the same law which is found to prevail over the physical organization of man's nature, although we may digest, assimilate, and combine, with different degrees of facility, the materials placed within our reach, we cannot, in a strict sense, create them ; and, accordingly, that no intellect, however vigorous—no imagination, however prolific—can operate to any good purpose, unless it has drawn largely from the intellectual stores of others, as well as from those accumulated by its own experience and observation.

It is thus that the majestic Aloe, which pushes forth innumerable blossoms in a single day, has had the materials which enabled it to achieve so astonishing an effort stored up within its cells by a long-continued process of assimilation, in readiness on the first favourable opportunity to become rapidly developed into an exuberance of flowers and of fruit.

The establishment of the doctrine of atoms affords another striking instance of a number of minute, trivial, and apparently only technical investigations concurring to build up a theory which, as Sir John Herschel has truly said, is perhaps, after the

laws of mechanics, the most important which the study of human nature has yet disclosed—a truth, indeed, which had occupied the minds of the first philosophers of antiquity, but which it was reserved for the experimentalists of the present age fully to substantiate.

Depending as it does on questions involving chiefly minute differences in weight and volume, it might seem at first sight to owe more to the skill of the balance-maker, and to the eye and hand of the operator, than to the sagacity which availed itself of the one, and which directed the other; but those who take this low view of the matter should be reminded that the father of the atomic theory himself was by no means famous for skill in manipulating, but derived most of his success from his penetration in interpreting, and in combining together the facts of others.

This association of minute details, with grand generalizations, will serve to show that Chemistry wields a weapon, like the trunk of an elephant, which can pick up a needle and uproot an oak; or may be compared to the Genie of the Eastern fable, who, although rather a dangerous and unruly servant when directed by rash or ignorant masters, would stoop to the homeliest, and accomplish the most stupendous labours, when brought under the dominion of the Lamp.

Nor, indeed, is Chemistry without its region of romance, even now that it has emancipated itself from the fictions of the Alchemist, and from the mysticism of the Rosicrucian philosophy.

The Philosopher who, by the aid of his crucible and his balance, can thus obtain glimpses of the ultimate constitution of matter—who can pronounce with so much confidence on the relative weight and volume of corpuscles too minute, not only to be recognized by the senses, but even to be conceived by the imagination—who can render it probable that many substances which defy our powers of analysis are nevertheless compounds, and have been made to reveal their elements to a subtler alchemy than that of actual experiment—invests his subject, I conceive, in some degree, with the same attributes of grandeur and sublimity which we associate with the contemplation of the great works of external nature.

Let me remind you, for instance, of the speculations which are naturally suggested by considering the mutual convertibility of the several imponderable agents, light, heat, electricity, magnetism; and by the relation of them all to mechanical force.*

Let me bring before you those suggestions of my late friend Dr. Prout, as to the probability of all elementary bodies being exact multiples of hydrogen, to the realization of which idea we seem to be brought nearer by every year's additional experience.†

And let me, by reference to the Table suspended in the room,‡ point out to you the still further relation which can be traced between the numbers representing the atomic weights of several of these elements—relations which, as some of you may recollect, induced M. Dumas, at the Ipswich meeting of the British Association, two years ago, to place certain of them in groups, each consisting of three members, and to conjecture that one of each triad might be a compound of the other two.

This, however, as has been pointed out in an ingenious paper by a young American chemist,§ from whom I have borrowed the Table just referred to, may probably be considered as an imperfect and partial view of the subject; and, it must be confessed, that in the existing state of our knowledge many hypotheses might be framed, all quite as plausible as that of the French philosopher.‖

Nevertheless, it can hardly be denied, after inspecting the

* See Mr. Grove's Pamphlet on *The Correlation of Physical Forces.*

† It has been suggested in the paper of the American chemist referred to just below, that the deviations from this rule, which still appear to exist in certain elements, may not always arise from error in experiment (although this is in most cases a sufficiently plausible explanation), but may hereafter be found to be a secondary result of the very cause which has determined the distribution of the atomic weights according to a numerical law, just as the perturbations in astronomy are a necessary consequence of the very law they seemed at first to invalidate.

‡ See Table I, p. 117, "Of the Relations between certain Elementary Bodies."

§ Mr. Cooke, Professor of Chemistry at Harvard College, in Cambridge, U.S.

‖ I cannot, however, admit the soundness of Mr. Cooke's suggestion that the atoms of the nine series are formed of an atom of oxygen as a nucleus, with the addition of one or more groups of atoms, each weighing nine, to which the corresponding element has not yet been discovered! We know that cyanogen, one of the series, is not so formed, for it is a compound of N 1 C 2, and as such, has been excluded from the list of bodies belonging to the nine series, although its atomic weight is $8 + n = 2$.

above Table, that there are really some remarkable relations between the atomic weights of those elements which are most nearly connected with each other by the circumstances of *homology* and of *isomorphism*, that is, by the similar proportions in which they respectively combine with other bodies, and by the similar crystallization of the resulting products.

These relations, indeed, admit of being expressed algebraically, in the case, at least, of some groups which have been most thoroughly investigated, just as may be done with reference to organic compounds, as may be seen by the Table of the Fatty Acids,* which is placed by the side of the one before referred to.

Hence there would seem in this respect to be an analogy between the simple radicals of inorganic bodies and the compound ones which are recognized as existing in Organic Chemistry, each member of the latter group being formed by the addition of C_2H_2, or a multiple of the same, to the atoms composing the lowest member in the series, namely, formic acid.

We may also detect in both instances a similar increase in density in proportion to the increase of atomic weight. Thus, in the former class of bodies, if we take the series of *nines*, oxygen is gaseous at all known temperatures and pressures; chlorine becomes liquid under four atmospheres; bromine is a volatile liquid at common temperatures; iodine, whose atomic weight is highest, exists as an easily volatilizable solid.

And in like manner, in the latter class of bodies, we find a transition from formic acid and methylic alcohol, substances of great volatility and low atomic weight, to the fatty acids, and to ethal, which are dense solids.

These generalizations, indeed, must not be allowed to warp our experimental conclusions; but they are eminently suggestive, and may be looked upon as examples of what may be termed the poetry of science, which is not without its use amongst the means of education, if only, like other poetry, it serves to impart a livelier conception of the beauty and harmony of creation, by affording experimental proof of that which the earliest sages of antiquity regarded as intrinsically probable,

* See Table II, p. 118.

namely, that God had " ordered all things in measure, number, and weight."

παντα μετρῳ καὶ αριθμῳ καὶ σταθμῳ διεταξας

The study of Chemistry seems to me also peculiarly adapted to initiate the youthful mind in the office of tracing the natural affinities betwixt bodies, and thus to induce methodical and systematic views of that subordination of properties which is the basis of all classification.

This is a service not to be rendered by the mathematical sciences, which proceed upon exact definitions, and habituate the mind to reject whatever does not come within the scope of rigorous deduction. For the relations between natural objects are based, not upon mutual identity, but upon degrees of resemblance; and the characters of each of them pass by such imperceptible gradations into the next in the series that every classification must, to a certain extent, be considered arbitrary, inasmuch as the limits of the divisions recognized can never be strictly defined.

Thus the class of metals graduates into that of the simple combustibles through the intervening links of sulphur and selenium; the acids into the bases through alumina; the supporters of combustion into the combustibles through sulphur and phosphorus; the electrics into conductors through the fibre of the nerves and muscles of animals.

The study of organic types, introduced by Dumas, and extended by Laurent and Gerhardt, may also initiate the mind in the idea which serves as a key to all the arrangements in the natural sciences—an idea which will be equally serviceable in grouping together the facts concerning our moral nature and the ordinary transactions of life, namely, that of adopting for our classification of bodies some character of primary importance, whilst we neglect those minor differences which must ever exist between one individual object and another.

Chemistry also appears to be calculated to afford useful lessons in the art of nomenclature.

In no other of the sciences has so perfect a specimen of this kind been exhibited as by Guyton Morveau, in his adaptation of the names of chemical substances to the theory of Lavoisier; and although the newer views entertained with respect to the

nature of the combinations then recognized may have rendered some part of this nomenclature inappropriate, yet its original merits may be estimated by the fact that no modifications in it have been proposed except what were forced upon us by changes in theory, and that the principal attempts at nomenclature since made have been rather extensions of the rules laid down in this scheme than a substitution of any new principle for the one which had served for their basis.*

But it is time to hasten on to the second branch of my subject—namely, the propriety of making Chemistry a part of that kind of primary instruction which aims at imparting a certain amount of general information to the youthful mind.

The crude notions so currently entertained with respect to what is called General Knowledge have created a prejudice against this Department of Education, which has induced many to contend that the sole aim of the latter is to train and develop the powers of the understanding.

Nevertheless, although nothing can be more absurd than to encumber the youthful mind with a heap of heterogeneous facts, without connexion one with the other, without interest to the pupil, and without any reference to his peculiar genius or future destination; yet it cannot be doubted that the period set apart for education is the one best fitted for storing up in the mind materials for thought, as well as those general principles and laws of the moral and physical world which are likely to be called into requisition in the course of his future life.

This, indeed, is acknowledged to be the case with reference to what concerns man as an individual and as a member of

* I would not defend the practice of affixing to *simple substances* names founded upon theoretical considerations, but conceive that, in the case of *compound ones*, it was a great gain to science, when Lavoisier substituted for the arbitrary designations then in use, words which at least indicated those ingredients by the union of which the bodies in question were commonly prepared. That oil of vitriol is obtained by combining sulphur with oxygen, and Glauber salt by bringing together sulphuric acid and soda, are facts sufficient to justify the names of sulphuric acid and of sulphate of soda assigned to these bodies; and their truth remains as before, whether we regard them with Lavoisier, respectivley S O 3 + H O, and S O 3 + Na O; or S O 4 + H, and S O 4 + Na, as the Binary Theory represents them. Nor would the *facts* be altered, even if the latter view of the constitution of salts, which is now in favour, were hereafter to be superseded by some other more plausible hypothesis.

society; on which accounts the events of history, the laws and constitution of our own country, and the principles of the philosophy of the human mind, hold a prominent part in every system of education.

But is it not also important, whatever our pupil's destination may be, that he should not leave us in entire ignorance of the laws and constitution of the objects that surround him—his companions from the cradle to the grave—bodies with which he will be brought into contact, as agents of good or of evil, at every moment of his existence?

And if the vast extent of the field thus opened be pleaded as a reason for limiting the student's range to particular branches of physical inquiry, those sciences which lie at the root of all our knowledge of the material world, and without some insight into which our acquaintance with individual facts must be merely empirical, unquestionably deserve the preference.

Now, if we classify the different departments of Natural Science, as I have done in the Table suspended in the room,* it will be manifest that the more fundamental ones, occupying the first division in the scheme submitted, will be those which comprise a knowledge of—

1. The general laws common to all matter whatsoever.

2. The special properties and relations of those bodies, which are either most familiar to us, most useful, or most

* NATURAL SCIENCE INCLUDES, AS PRIMARY, OR FUNDAMENTAL BRANCHES, A KNOWLEDGE OF

The properties common to all matter—Physics . .	Celestial. / Terrestrial.
The properties distinctive of Bodies in general—Chemistry	Inorganic. / Organic.
The properties distinctive of living Bodies in particular—Physiology	Vegetable. / Animal.

AS SPECIAL OR SUBORDINATE BRANCHES, THE NATURAL HISTORY OF

Inorganic bodies, viz.	Of the Atmosphere . . .	Meteorology.
	Of the Earth and its contents .	Mineralogy Lithology. Geological Dynamics. Palæontology.
Organic bodies, viz.	Of Vegetables . . .	Systematic Botany. / Organography.
	Of Animals. . . .	Zoology. / Anatomy.

generally diffused throughout nature, so far as they are not influenced by vital forces.

3. The general laws which govern life, both as it exists in the animal and in the vegetable kingdom.

Of these, the first named is termed mechanical philosophy, or physics; the second is included under chemistry; the third under general physiology.*

With regard to those other departments of natural science which often enter, to a certain extent, into a scheme of popular education, it may be remarked that in so far as they are parts, not of natural history, but of philosophy, they are to be regarded simply as expansions of, or as deductions from, one or other of the primary ones before cited; and therefore cannot be acquired, except as mere aggregates of undigested facts, until a knowledge of some one at least of the above fundamental sciences has been attained.

Thus let us take the case of geology, and suppose our pupil, just emancipated from school or college, to find himself at the foot of a volcano, and to witness some of the more striking manifestations of subterranean energy there exhibited. Sublime and impressive as the spectacle may be, how entirely will he be in the dark, not only as to the cause of the movement, but even as to the nature of the phenomena which he witnesses, if unaided by chemistry. What will he know of the constitution of the substances ejected, of the gases and vapours evolved, or of the condition of the surface overspread by these volcanic materials, which is sometimes so favourable, at other times so unpropitious to vegetation?

With how much more abiding an interest will he contemplate the phenomena, when he views them in connexion with any chemical hypothesis, which, however conjectural, as every hypothesis must be which relates to processes going on so far beyond the limits of human observation, professes at least to account for the particular events that come before him, as well as for the order of their sequence.

Or let him turn his steps to a country where extensive rocks are forming, not by igneous forces, but by slow deposition

* See this explained in a pamphlet of mine, entitled, *Brief Remarks on the Correlation of the Natural Sciences.* Oxford: Vincent, 1848.

from water, as in the Travertine of Italy, of which the most celebrated temples of Rome, as well as those of Pæstum, are constructed. How much greater interest will he feel in them, when, by the lights of chemistry, he traces the action which had brought about their deposition, the relation which they bear to stratified rocks of older formation, and the probable source of the carbonic acid which communicated its solvent power to the waters of the district.

Or suppose him to direct his attention to those branches of natural history which relate to living beings, and to concern himself, not merely in the external forms of animals or plants, but also in their structure and functions.

Such inquiries will make him acquainted with the law of Endosmose, which, as the physiologist will inform him, is seen in operation during every process of secretion and excretion which takes place in the animal or vegetable kingdom, but which the chemist will trace to the still more widely operating law of Diffusion, which is seen alike in gases and in liquids, in organic and in inorganic bodies, as the late researches of Liebig and of Graham have explained to us.

Or if the occurrence of one of those epidemics, which have of late years been so frequent, should call his attention to the laws of contagion, even here the most philosophical explanation of the spread of the disease may be afforded him by the suggestions of a chemist, who has traced a very close analogy between the propagation of miasmata in the animal organism, and the transmission of the fermentative process in fluids susceptible of change from one to the other; referring both to a law common alike to living and to dead matter, which renders any motion set up in one compound liable to extend itself to others, whose particles are in a similar condition of unstable equilibrium.

It will be seen that I have drawn my examples from subjects which at first sight appear to be as far removed as possible from the jurisdiction of Chemistry, for it seemed to me needless to remind the audience I am addressing that a Science which embraces under its consideration all those properties which are not either common to all bodies whatsoever, or, on the other hand, attributable to the agency of the vital principle, must be indispensable to the due understanding—of the processes of the

manufactures—of the operations of agriculture—of all the changes, in short, in the material world which take place through the instrumentality either of art or of nature.

I need not, therefore, detain you with discussing a truth so self-evident; but will proceed to consider how far the study of this science can, without unduly displacing others, be made to constitute a part of the education of the different classes of society.

And first, with respect to that of the lower orders—upon which, however, I should hardly venture to pronounce, if I were not backed by the authority of others, who have made this subject their particular study, and especially the Dean of Hereford, whose diligence and success in organizing schemes of secular education for the people are now fully appreciated. There are many subjects upon which a knowledge of a few elementary facts in Chemistry will not only supply food for the mind, but also convey useful practical hints to the labouring population of our towns and villages.

I may mention, amongst the rest, economy with regard to the selection of food, and its preparation for human subsistence by the modes of cooking in common use—provisions for the better ventilation of cottages, and for their sanitary condition generally—instruction with respect to handicraft work and various mechanical occupations—information with respect to the different qualities of water, and its relative fitness for washing and drinking purposes.

The Dean has pointed out with how very simple and inexpensive an apparatus the village schoolmaster may demonstrate some of the leading truths which illustrate these several heads of information, and thus impress them more vividly upon the minds of his pupils than could be done by mere oral instruction.

If from the lowest class of society we pass on to those higher in the scale, who are designed for various trades and manufactures, for the pursuits of agriculture, or for the inferior grades in the professions of law and medicine; we shall see reasons for recommending to them the study of chemistry, both as a discipline for the mind, and also as the basis of much useful and practical knowledge.

In their case, the necessity of commencing at an early age the active business of life precludes the possibility of entering deeply into the mathematics, and therefore renders it more important that the gap should be supplied by the study of a science which may, to a certain extent, supply its place, by training and developing the mental faculties.

The pupil, if agriculture is to be his future calling, will learn from chemistry how to economize his manures; how to bring the land in a condition to impart its latent resources to the crop; how to supply what is necessary for the growth of the plant he cultivates.

Without superseding the necessity of experience, or of that vigilant survey of his farming operations, which of all requisites is the one most essential to success, science will be valuable both in suggesting new modes of culture, and in enlightening him as to the causes of failure, when the ordinary system of operations has chanced to disappoint his expectations.

We have heard, indeed, of cases where, after the scientific man has corrected the practical, the result has proved the latter to have been in the right; but in those instances it has generally turned out upon inquiry that the error was to be attributed to the imperfection of our knowledge, and that the correction must be applied by a more complete scientific investigation of the subject.

Thus, the chemist has often reprobated the practice adopted in some of the western counties of adding quicklime to manure-heaps, as tending to dissipate the ammonia disengaged before it could influence the crop. Lately, however, we have been reminded that nitric acid, as well as ammonia, is produced during the process of animal putrefaction, and that the former, instead of being dissipated, would be only more effectually fixed by the application of an alkaline earth to the substances containing it.

The practice, therefore, is not so improper as it had appeared from theory to be; but the practical man should nevertheless be reminded that the aid of chemistry is required to enlighten him under what conditions the first or the second of these products is elicited,* so that he may learn when lime may be added with advantage, and when with loss.

* See Kuhlman's Papers on the production of Nitre.

Probably indeed, in the west-country practice alluded to, the addition of an absorbing substance to the manure-heap may serve to counteract the bad effects of the quicklime, even where ammonia is the principal product; but the farmer, who should imitate this practice without understanding the conditions upon which its success depends, would be very likely to omit these accessories, and thus to bring about an opposite result.

With regard to the applications of Chemistry to the useful arts, the instances of it are so numerous and so familiar to all that it seems needless to insist upon the advantages of its study to all who are destined for such employments; and it is equally clear that, for those who intend to make the healing art, in any of its branches, their future profession, a more than superficial knowledge of it is all but indispensable.

I proceed, then, to consider how far Chemistry deserves a place in that more complete system of education which is designed for the learned professions, as well as for the higher Orders of Society in general. My recommending it as a fit study for the middling and the lower classes would alone render it imperative upon me to impose it upon the upper—for under the circumstances of the present age, and in this country more especially, the maintenance of a superior position, and of superior moral influence, involves the necessity of superior mental culture.

The idea of imparting a special direction to the primary education of youth, in accordance with their respective rank or future destination, is not only in itself unphilosophical, but also in manifest contradiction * to the principle which has always guided us in our schools and colleges—namely, that of exacting from all for whom a liberal education is designed the same basis of classical and mathematical learning. And the adoption of an opposite principle, by the exclusion from the curriculum of any study which is admitted as an integral part of the training given to the people at large, must tend to the isolation of the class to which it is applied, and consequently weaken its connexion with those below it.

* See Davison's Remarks on this subject, and Father Newman's *Discourses on University Education*, p. 241 *et seq.*

In a Protestant community, for example, the legitimate influence of the priest over the laiety can only be duly maintained by the ascendancy of his character, and by the extent of his information with respect to subjects on which the people with whom he mixes are able to estimate his superiority.

By enlightening them on common matters, in which a little knowledge of Chemistry will afford them such material assistance, and thereby becoming the instrument of enabling them to better their own condition, and to economize their means of living, he paves his way to their confidence on subjects more strictly appertaining to his sacred profession.

There seems to me also to be a peculiar propriety in thus intercalating a somewhat fluctuating, though advancing science, like Chemistry, in a course of education, the principal elements of which, such as the mathematics or the literature of past ages, are little susceptible of change.

A study of this description familiarizes the pupil with the idea of progress; it exercises a distinct set of faculties, just as a new gymnastic exercise calls into play a new set of muscles; and it guards against that stagnation which is apt to supervene, when the mind is chiefly made the passive recipient of truths which rest upon authority.

To those, indeed, who regard a knowledge of what other men have said and done, the sole aim of education, the example of the Chinese may serve as an instructive warning.

We here see a nation which has retrograded in the scale of civilization, in consequence of having reposed entirely upon the wisdom of its ancestors; of following implicitly those principles in the arts which had been handed down to it from an early period; and of occupying its learned leisure chiefly in pondering over the intricacies of a language which it would seem to require the labour of a life fully to master.

It must indeed be confessed, in justice to this people, that they had a better excuse for their tenacity in adhering to their ancient paths than other nations would be able to plead. Long before Europe had emerged from barbarism, China was in possession of the art of printing, of gunpowder, and of the mariner's compass—her population was clad in silks, a royal luxury even in the days of Queen Elizabeth—had perfected the

manufacture of porcelain—and had brought agriculture and many of the industrial arts to a high pitch of perfection. Her vast empire enjoyed a patriarchal government; an aristocracy founded only upon the enlightened principle of intellectual superiority, tested by public competition; a complete system of internal communication by roads and canals; and a code of laws which, viewed even by the lights of the present day, is considered by good judges to savour throughout of practical sagacity and European good sense.

Is it to be wondered at that surrounded as she was with hordes of mere savages, and receiving no favourable report, if any, of nations more distant, China should have overestimated both her material and her intellectual superiority, and should have imagined that in her palmy condition change was the only danger against which she had to guard?

And yet, after ten centuries of stagnation, what is the spectacle this nation presents to us? a population at once effeminate and degraded, inferior to ourselves even in those industrial arts, on which they chiefly plume themselves, and incapable of adopting to any extent the inventions of other nations—a monied class sordid and sensual—and a body of Literati indifferent to all abstract science, and curious only on points of information which promise some palpable and immediate end of utility.

It is of course foreign from my intention to compare the philosophy of Confucius with that of Aristotle, or the literary productions of a Mongolian nation with those which emanated from the highest type of intellect which the human race probably has ever developed; but the evil consequences I have pointed out seem to me to have arisen, not so much from the inferior character of the models held out for them to copy, as from their servile adherence to them.

"Truth," says Milton, "is compared in Scripture to a streaming fountain; if her waters flow not in a perpetual progression, they sicken into a muddy pool of conformity and tradition;" and all experience will serve to show that wherever due provision has not been made for advancement the seeds of decay are sure to find admittance.

Hence, if on the one hand it be useful to impress upon the mind a reverence for the great lights that have illumined the

walks of learning in former periods of the world ; it is not less desirable on the other that some of the studies pursued in early youth should have a tendency to encourage an independent search after Truth, and to induce the habit of interrogating nature as well as of leaning upon the traditions of men.

With these sentiments it may be supposed that I am not prepared to defend the system pursued in my own university till within the last two years, which consisted in merely securing the delivery of lectures on Chemistry for the sake of those who might desire, of their own accord, to improve themselves in that science, without holding out any encouragement to its prosecution, or treating the subject as though it were considered in any sense an integral part of our scheme of education.

In these respects, however, Chemistry was at least in no worse position than other branches of physical science, or even than the history and philosophy of modern times, no one of which studies was insisted upon, or even promoted amongst us by academical distinctions or emoluments.

The defenders of this exclusive system might, indeed, appeal to the long train of distinguished men whom the university had sent forth, as a practical proof of its efficacy in refining and expanding the mental powers ; and I am far from disputing the position that, supposing the attention of youth required to be limited to one description of literature, the great writers of antiquity deserve in many respects a preference over those of later times. There is a simple grandeur, an absence of all affectation and straining after effect, a native vigour and freshness about the early Greek writers in particular, which seem better calculated to win the sympathies of youth, and to induce habits of just thinking and correct taste, than the more elaborate and recondite productions of men of modern days.

The faults, as well as the beauties of these authors, are those of precocious youth ; and if we were to suppose a Being of a superior order to man to appear upon our globe, although his matured intellect might strike out deeper truths, and teem with loftier imaginations, his earlier thoughts might be imagined to find their most appropriate expression in the language of Homer or of Herodotus.

Nevertheless, the advocates of a purely classical education

appear to have overlooked certain considerations which are not without weight in arriving at a right conclusion on such a subject.

In the first place, as I have already remarked, it is desirable to train and develop the faculty of minutely observing, of clearly apprehending, and of correctly classifying the objects that present themselves; talents which can be best fostered at an early period of life, and can in no way be more fully unfolded than by a course of chemical study.

Secondly, the many urgent motives, of one kind or another, which force the student to plunge into active life immediately upon escaping from the trammels of the school or university, will often prevent his possessing any sound knowledge of physical science, if it be not made a part of his early education.

Lastly, a very large proportion of mankind want the ability to obtain that proficiency in any of the branches of learning cultivated at our universities which is requisite to enable them to reap from their study the advantages anticipated.

In an Institution intended to educate the youths of the country generally, however high the qualification for distinction may be raised, a low standard of attainments can alone be insisted upon; and yet it is notorious that a large proportion of the youths who resort to a university, although they are capable of reaching the prescribed point with little mental exertion, never aspire to go beyond it.

Nor is this indifference on their part to be ascribed, primarily at least, to indolence of disposition, or to deficiency in ordinary intelligence; for these very persons in after life will often evince much power of application, and soundness of judgment, in the capacity of magistrates, of parochial clergymen, or even of members of the legislature. Their previous intellectual torpor, so far as all academical studies were concerned, arose, I am convinced, in a great degree, from their incapacity to grapple with the deeper philosophy of the ancient world, or to imbibe any keen relish for its orators, its poets, or its historians.

If to this inaptitude for literary pursuits be conjoined an equal disinclination for abstract studies or for the higher branches of the mathematics, one can readily understand that

such youths should make but little progress beyond the point to which they had already advanced at school, and that the time spent at the university should have been chiefly wasted in field sports, or even more frivolous occupations.

Now it is for men of this character of mind that the study of the experimental sciences is particularly valuable, because the very practical tendency of their minds, which, to a certain extent, prevents them from profiting so largely from the favourite studies of a university, is the very quality most likely to befit them for the observation of external nature, and is, moreover, most commonly accompanied with that tact and sagacity which are most serviceable in its interpretation.

Thus the recognition of Chemistry in a university like the one to which I belong is little likely to detract unduly from the attention paid to the classical studies of the place; whilst its pursuit is only so much clear gain to the general stock of knowledge, as it would be chiefly confined either to youths who are not likely to apply themselves with any vigour and success to literary subjects; to those who have a peculiar genius and aptitude for physical investigations; or, lastly, to the few who have energy and capacity enough to embrace both literature and science within the circle of their studies.

It was not, therefore, without good reason that the University of Oxford, in the year 1849, determined that henceforward the physical sciences should be made the subjects of examination, and be held out to its students as reckoning amongst the qualifications, not only for a simple degree, but also for certain academical distinctions.

But something more than this will be required, if we would secure to these branches of study their proper place in such a body as our own. In order to afford effectual encouragement to any department of learning, substantial rewards are necessary, and fortunately the liberality of our Founders and benefactors has supplied us with means ample enough, if judiciously applied, to spread their fertilizing influence over every field of intellectual culture, instead of being limited, as at present, to a few.

At any rate, as I have observed in another place,* no one can

* See a Pamphlet entitled, *Can Physical Science find a Home in an English University?* Oxford: Vincent, 1854.

have a right to pronounce the atmosphere of Oxford uncongenial to the investigation of physical truth, until it has been ascertained what would be the result, supposing a certain proportion of our Fellowships were awarded as prizes for scientific acquirements; and supposing, as would be the natural consequence, that the student who distinguished himself in this line were placed, in the estimation of his contemporaries, on the same level as if he had bestowed a similar amount of mental exertion upon pursuits of a literary character.

If this rule were adopted, there seems to me no reason why Oxford should not rank as high in physical science as she has long done in other departments of human knowledge; for I, for one, cannot understand why the contemplation and study of nature should not be carried on at least as well within the retirement of a university as amidst the noise and bustle of a crowded metropolis.

It would rather seem that for the prosecution of experiments requiring often considerable abstraction of mind, as well as long-continued exertion; and promising no immediate result, beyond the pleasure of arriving at a new truth, the pecuniary resources of our collegiate establishments, and the exemption they afford from the cares and distractions of ordinary life, supply the most ample facilities; and that whilst the prospect of attaining a Fellowship might attract students into this path of research, the possession of one would afterwards enable them to dedicate their lives to its prosecution.

And this application of our academical funds is, I contend, entirely in harmony with an enlightened view of the objects for which they were designed; for although the older universities of the realm were, doubtless, primarily intended, as those of later creation are, for the purposes of education, they, from the very first, aimed at something beyond it.

The entire tendency of the collegiate system—the foundation of fellowships—their tenure extending far beyond the period to which the education of their holders could be supposed to be prolonged, and in most cases, indeed, without any limitation as to the period of their retention—are circumstances all of which imply that the views of our Founders contemplated the creation of a permanent body of men devoted to the prosecution

of literary and scientific objects, under the presiding influence of religion.* There is, indeed, no other possible explanation of their motives, unless we were to adopt the monastic view of these Institutions, which the perverse ingenuity of a few persons of late years has ventured to uphold; but which was disavowed by their own Members at the time of the Reformation, as a plea of exemption from the common fate which then awaited the Religious Houses; and which seems to have been repudiated by the earliest and most catholic-minded of our Founders, in

* Although the Bill now before Parliament for furthering the good government of the University and of the Colleges has in general my hearty concurrence, there are, nevertheless, two provisions in it which I cannot but consider as detrimental to the interests of Oxford, whether regarded in the light of a focus of literature, or as a nursery of education.

I allude to the clause fixing a limit to the tenure of Fellowships, and to that rendering residence, except in a few particular cases, compulsory upon those who enjoy them.

The former of these appears to be calculated to check the growth of a class of men, at present perhaps not very numerous, but which it is highly important to foster—those I mean who devote themselves to literary and scientific occupations without any ulterior object in life: nor can it fail to damp the exertions even of others who come to us for education, since it will deprive the academical emoluments, which are held out to them as the rewards of success, of a considerable portion of their value.

It ought not to be overlooked that a Fellowship is coveted less on account of its pecuniary amount than for the security it affords that its possessor may hold it for any length of time, if his necessities or ill success in life should render it of importance for him to retain it.

It thus serves as a guarantee to the disinterested and unambitious student that he will be free to prosecute his favourite pursuits so long as he pleases, in comparative indifference as to their bearing upon the practical concerns of life, or on his own future advancement in it. And with respect to the abuses complained of at present in the tenure of Fellowships, I have sufficient faith in the working of the Bill to conceive that when Colleges have the power of selecting candidates from the whole University, the cases will be few where a Fellow shall linger on, as a burden to his Society, beyond the period which the interests of learning would justify; and if this were to happen now and then, the evil would be small compared to that of spreading abroad the feeling that inasmuch as the provision made for study is henceforward to cease at the period of life when it may be most wanted, the application of any portion of the means supplied to obtain other than personal objects would be an act of imprudence.

On the other hand, the clause compelling residence strikes me as either unnecessary or injurious; unnecessary when the Fellowships are properly bestowed, and of an injurious tendency when they are not.

Supposing, for instance, the successful candidate to possess literary tastes and attainments, why seek to compel him to do that to which his own inclinations would naturally prompt him and from which he would only be drawn aside when, as in the case of a lawyer or physician, his studies could be more advantageously prosecuted elsewhere?

On the other hand, supposing the Fellowship to be filled up without due reference to the claims of merit, the enforcement of residence would have the

the distinct prohibition which their statutes contain against any member of a conventual establishment holding a position within our colleges.

I should apologize, Gentlemen, for detaining you so long on these topics if I did not feel that the English universities not only are, but will be recognized by you all as national establishments—national, not only because there is perhaps no one in an assembly like the present whose nearest relatives may not at some time or other be assisted in their education by the scholarships, or rewarded for their exertions by the Fellowships, of which we have the disposal; but also because the existence of a high standard of education anywhere within our common country is a national benefit even to those who do not directly partake of it.

It would seem a happy circumstance that in a country of great proprietors like our own, some portion of the land should have been removed from the grasp of individuals, by being held, as it were, in mortmain for the benefit of the community at

effect of fixing at the University men of uncongenial habits, whose presence must be equally detrimental to themselves and to others.

It would indeed be a singular act of inconsistency in the members of the Legislature if, when they felt themselves authorized by considerations of public utility to overrule the injunctions of Founders with respect to matters in which the most earnest reformers within our walls have felt themselves precluded, from conscientious motives, from proposing changes; they should at the same time compel us to return to our statutes on a point wherein the altered condition of Society reconciles the most scrupulous of our members to that departure from their strict letter which has long taken place.

The enforcement of residence upon Fellows, beyond the amount necessary for the purposes of instruction, and of carrying on the concerns of the College, could only have reference, in the minds of Founders, either to the advancement of learning or to the observance of monastic discipline.

So far as the former was their object, it would at present be sufficiently consulted by the many inducements to residence which the University holds out to the real student; if the latter made any part of their intentions, Parliament, in the nineteenth century, can hardly desire to go out of its way to further them, by inculcating, or rendering more inveterate, those conventual habits and feelings which cause religious observances to be regarded, not as the proper preparation for the duties of life, but as its sole business; this latter being the only assignable ground for enforcing residence in Colleges on persons not fitted or disposed to avail themselves to any extent of the means and appliances for literary occupation which Oxford so abundantly affords.

P.S. June 10th. The above clauses are, I am happy to see, excluded from the Bill "as amended in Committee and on recommitment," but provisions of a similar tendency seem still to be left within the powers with which the Commissioners are to be invested.

TABLE I

TABLE OF THE RELATIONS BETWEEN CERTAIN ELEMENTARY BODIES

	Isomorphs.			Homologues.		Atomic Weights. By Theory.	By Experiment.	Numerical Relation.	Dumas' Calculation.
The Nine Series. $8 + n\,9$	Cu 2 O		. Oxygen	H O		8	8·0	$n = 0$	
	Cu 2 Cl K Cl		.. Chlorine	H Cl		35	35·5	$n = 3$	17·5
			.. Bromine	H Br		80	80·0	$n = 8$	
			.. Iodine	H I		125	126·9	$n = 13$	62·5
									80·0
The Eight Series. $8 + n\,8$		Pb S	.. Sulphur	H S		16	16·0	$n = 1$	8·0
		Pb Se	.. Selenium	H Se		40	39·6	$n = 4$	
		Pb Te	.. Tellurium	H Te		64	64·1	$n = 7$	32·0
									40·0
The Six Series. $8 + n\,6$			Nitrogen	N O 3		14	14	$n = 1$	
	Na O, P O 5 + H O		.. Phosphorus	P O 3		32	32	$n = 4$	
	Na O, As O 5 + H O	As O 3	.. Arsenic	As O 3		74	75	$n = 11$	Fails.
	Sb O 3	Sb O 3	.. Antimony	Sb O 3		128	129	$n = 20$	
	Bi O 3		.. Bismuth	Bi O 3		206	206	$n = 33$	
The Three Series. $1 + n\,3$			Hydrogen	H O		1	1·0	$n = 0$	
		Li Cl	.. Lithium	Li O		13	13·0	$n = 4$	6·5
		Na Cl	.. Sodium	Na O		46	46·0	$n = 15$	
		K Cl	.. Potassium	K O		79	78·4	$n = 26$	49·5
									56·0
The Four Series. $4 + n\,4$		Ca O, C O 2	.. Calcium	Ca O	Ca O 2	20	20·0	$n = 4$	10
		Sr O, C O 2	.. Strontium	Sr O	Sr O 2	44	43·8	$n = 10$	
		Pa O, C O 2	.. Barium	Ba O	Ba O 2	68	68·5	$n = 16$	34
									44

TABLE II

TABLE OF THE RELATIONS BETWEEN THE SEVERAL FATTY ACIDS

			Dumas' Calculation.
	.... Formyle	C 2 H 1	
	generates		
(C 2 H 1 O 3) + n = (C 2 H 2)	.... Formic Acid . . .	C 2 H 1 + O 3 + HO = n = 0	.... C 1 H 0·5
	.... Acetic	C 4 H 3 + O 3 + HO = n = 1	
	.... Metacetonic . . .	C 6 H 5 + O 3 + HO = n = 2	.... C 3 H 2·5
	.... Butyric	C 8 H 7 + O 3 + HO = n = 3	
	.... Valerianic . . .	C 10 H 9 + O 3 + HO = n = 4	C 4 H 3
	.... Caproic	C 12 H 11 + O 3 + HO = n = 5	
	.... Œnanthylic . . .	C 14 H 13 + O 3 + HO = n = 6	
	.... Caprylic	C 16 H 15 + O 3 + HO = n = 7	
	.... Pelargonic . . .	C 18 H 17 + O 3 + HO = n = 8	
	.... Capric	C 20 H 19 + O 3 + HO = n = 9	
	.... Lauric	C 24 H 23 + O 3 + HO = n = 11	.... C 12 H 11·5
	.... Cocinic	C 26 H 25 + O 3 + HO = n = 12	
	.... Myristic	C 28 H 27 + O 3 − HO = n = 13	.... C 14 H 13·5
			C 26 H 25
	.... Palmitic	C 32 H 31 + O 3 + HO = n = 15	
	.... Margaric	C 34 H 33 + O 3 + HO = n = 16	

large; and not less so that amongst a nation so absorbed in the pursuit of wealth, and holding out to all classes such strong temptations to plunge into active life at as early a period as possible, establishments should exist, by the aid of which the educated classes may be induced to linger a little over those studies which exert a generous and ennobling influence upon the character of a people, and tend to counteract the too practical and utilitarian tendencies of the age in which we live.

The genius of Oxford, indeed, has, I believe, on many occasions operated beneficially upon the general surface of English society. May we not also hope that, in return, those without her walls may react with advantage upon the university itself, by putting forth so strong an expression of public opinion as may induce our Members to hold for the future in equal esteem, and to foster with an equal degree of encouragement each one of the liberal branches of intellectual culture.

Should such hereafter be the case, and should the application of a portion of our endowments to the advancement of physical science be admitted as a natural consequence of such a view, great indeed would be the stimulus thus afforded to this class of pursuits, and great the advancement in the sciences which might be expected to accrue.

The English universities might then again become, as they were of old, the principal seats of physical research, as well as the main repositories of existing knowledge in the country; and as at the present time the amateurs of science at Oxford wend their way to the Royal Institution to obtain the first announcement of the researches of a Faraday, so it may happen that at some future day the inhabitants of the metropolis may be induced to crowd to our University in order to become acquainted with the discoveries worked out by some new Roger Bacon, within the cloisters of his Academic Home.

ON THE IMPORTANCE OF THE STUDY OF PHYSICS AS A BRANCH OF EDUCATION FOR ALL CLASSES

A LECTURE DELIVERED AT THE ROYAL INSTITUTION OF GREAT BRITAIN

By PROFESSOR TYNDALL, F.R.S.

THERE is a word in the title of this Lecture which does not clearly convey the idea by which I shall be guided in its delivery. I hold in my hand a soiled proof of the syllabus of the present course, and the title of the present lecture is there stated to be "On the Importance of the Study of Physics as a *Means* of Education." The corrected proof, however, contains the following title: "On the Importance of the Study of Physics as a *Branch* of Education." Small as the alteration may seem from means to branch, the two words appear to me to suggest two radically distinct modes of viewing the subject before us. The term Education is sometimes applied to a single faculty or organ, and if we know wherein the education of a single organ or faculty consists, this knowledge will enable us to form a clearer notion regarding the education of the sum of all the faculties, or of the mind. When, for example, we speak of the education of the voice, what do we mean? There are certain membranes at the top of the windpipe which are capable of being thrown into vibration by the air forced between them from the lungs, and thus caused to produce sound. These membranes are, to some extent, under the control of the will: it is found that they can be so modified by exercise as to produce notes of a clearer and more melodious character, and this exercise we call the education of the voice. We may choose for our exercise a new song or an old song, a festive song or a solemn chant; and, the education of the voice being the object we have in view, the

songs may be regarded as the *means* by which this education is accomplished. I think this expresses the state of the case more clearly than if we were to call the songs a *branch* of education. Regarding also the education of the human mind as the improvement and development of the mental faculties, I consider the study of Physics to be a means towards the attainment of these objects. Of course, from this point of view, I degrade Physics into an implement of culture, and I mean to do so, to a great extent; for the general expansion of the intellectual powers implies both the acquisition of specific knowledge and the ability to render it productive. There is this great difference between those who pursue a thing as a branch and those who use it as a means: in the latter case the knowledge imparted is truly power; whereas, in the former case, it may be the reverse. Viewing, then, the development of the mental faculties as the end of mental education, it will be my endeavour to state to you some of the claims of Physical Science as a means towards the attainment of this end.

I do not think that it is the mission of this age, or of any other particular age, to lay down a system of education which shall hold good for all ages. The basis of human nature is, perhaps, permanent, but not so the forms under which the spirit of humanity manifests itself. It is sometimes peaceful, sometimes warlike, sometimes religious, sometimes sceptical, and history is simply the record of its mutations.

> "The eternal Pan
> Who layeth the world's incessant plan
> Halteth never in one shape,
> But for ever doth escape
> Into new forms."

This appears to be the law of things throughout the universe, and it is therefore no proof of fickleness or destructiveness, properly so called, if the implements of human culture change with the times, and the requirements of the present age be found different from those of the preceding. Unless you can say to me that the past world, or some portion of it, has been the final expression of human competency; that the wisdom of man has already reached its climax; that the intellect of to-day possesses feebler powers, or a narrower scope than the intellect of earlier times; you cannot, with reason, demand from me an unconditional acceptance of the systems of the past, nor are you

justified in divorcing me from the world and times in which I live, and confining my conversation to the times gone by. Who can blame me if I cherish the belief that the world is still young; that there are great possibilities in store for it; that the Englishman of to-day is made of as good stuff, and has as high and independent a vocation to fulfil, as had the ancient Greek or Roman. While thankfully accepting what antiquity has to offer, let us never forget that the present century has just as good a right to its own forms of thought and methods of culture as any former centuries had to theirs, and that the same sources of power are open to us to-day as were ever open to man in any age of the world.

In the earliest religious writings, we find man described as a mixture of the earthly and the divine. The existence of the latter implies, in his case, that of the former: and hence the holiest and most self-denying saint must, to a certain extent, protect himself against hunger and cold. But every attempt to restrict man to the dominion of the senses has failed, and will continue to fail. He is the repository of forces which push him beyond the world of sense. He has an intellect as well as a palate, and the demands of the latter being satisfied, the former inevitably puts in its claim. We cannot quench these desires of the intellect. They are stimulated by the phenomena which surround us in our present state of existence as the body is by oxygen; and in the presence of these phenomena man thirsts for knowledge as an Arab longs for water when he smells the Nile. The Chaldean shepherds could not rest contented with their bread and milk, but made the discovery that man had other wants to satisfy. The stars shed their light upon the shepherd and his flock, but in both cases with very different results. The quadruped cropped the green herbage and slept contented; but that power which had already made man the lord of the quadruped was appealed to night after night, and thus the intellectual germ which lay in the nature of these Chaldeans was stimulated and developed. Surely, if man be not made, and stars scattered, by guess-work, there is strong reason for assuming that it was intended that mental power should be developed in this way. As the nurse holds her glittering toy before the infant that she would encourage to take its first step, so it would appear as if one of the ends of the Creator, in setting

those shining things in heaven, was to woo the attention and excite the intellectual activity of his earthborn child. But if this be granted, then it must be admitted that we have the very highest sanction for the prosecution of physical research. Sanction, indeed, is a term too weak to express the inference suggested by a comparison of Man's powers with his position upon earth ; it points to an imperative command to search and to examine, rather than to a mere toleration of physical inquiry.

The term Physics, as made use of in the present Lecture, refers to that portion of natural science which lies midway between astronomy and chemistry. The former, indeed, is Physics applied to masses of enormous weight, while the latter is Physics applied to atoms and molecules. The subjects of Physics proper are, therefore, those which lie nearest to human perception—the light and heat of the sun, colour, sound, motion, the loadstone, electrical attractions and repulsions, thunder and lightning, rain, snow, dew, and so forth. The senses of Man stand between these phenomena, between the external world and the world of thought. He observes the fact, but is not satisfied with the mere act of observation : he must render an account of the fact : he takes his images from Nature and transfers them to the domain of thought : he looks at them, compares them, observes their mutual relations and connexions, and thus brings them clearer and clearer before his mental eye, until, finally, he alights upon the cause which unites them. This is the last act of the mind, in this centripetal direction, in its progress from the multiplicity of facts to the central cause on which they depend. But, having guessed the cause, he is not yet contented : he now sets out from his centre and travels in the other direction : he sees that if his guess be true, certain consequences must follow from it, and he appeals to the law and testimony of experiment whether the thing is so. Thus he completes the circuit of thought—from without inward, from multiplicity to unity, and from within outward, from unity to multiplicity. He traverses the line between cause and effect both ways, and, in so doing, calls all his reasoning powers into play. For the mental effort involved in these processes may be justly compared to those exercises of the body which invoke the co-operation of every muscle, and thus confer upon the whole frame the benefits of healthy action.

The first experiment a man makes is a physical experiment: he is a natural philosopher by instinct, and the suction-pump is but an imitation of the first act of every new-born infant. Nor do I think it calculated to lessen that infant's reverence, or to make him a worse citizen, when his riper experience shows him that the atmosphere was his helper in extracting the first draught from his mother's breast. The child grows, but is still an experimenter: he grasps at the moon, and his failure teaches him to respect distance. At length his little fingers acquire sufficient mechanical tact to lay hold of a spoon. He thrusts the instrument into his mouth; hurts his little gums, and thus learns the impenetrability of matter. He lets the spoon fall, and jumps with delight to hear it rattle against the table. The experiment made by accident is repeated with intention, and thus the young Newton receives his first lessons upon sound and gravitation. There are pains and penalties, however, in the path of the young inquirer: he is sure to go wrong, and Nature is just as sure to inform him of the fact. He falls downstairs, burns his fingers, cuts his hand, scalds his tongue, and in this way learns the conditions of his physical well-being. This is Nature's way of proceeding, and it is wonderful what progress her pupil makes. His enjoyments for a time are physical, and the confectioner's shop occupies the foreground of human happiness; but the blossoms of a finer life are already beginning to unfold themselves, and the relation of cause and effect dawns upon the boy. He begins to see that the present condition of things is not final, but depends upon one that has gone before, and will be succeeded by another. He becomes a puzzle to himself; and to satisfy his newly awakened curiosity, asks all manner of inconvenient questions. The needs and tendencies of human nature express themselves through these early yearnings of the child. He desires to know the character and causes of the phenomena presented to him; and unless this desire has been granted for the express purpose of having it repressed, unless the attractions of natural phenomena be like the blush of the forbidden fruit, conferred merely for the purpose of exercising our self-denial by letting them alone; then I claim for the study of Physics the recognition that it answers to an impulse implanted by nature in the human constitution, and he who would oppose such study must be prepared to exhibit the credentials which

authorize him to contravene Nature's manifest designs. Such credentials were never given; and the opposition, where it exists, is in most, if not in all cases, due to the fact that at the time when the opponent of Science was beginning to inquire like the little boy, it was so arranged by human institutions that the train of thought suggested by natural objects should, in his case, be supplanted by another. But is this unavoidable? Is, for example, the knowledge of grammatical concord and government so utterly antagonistic to the scientific discernment of the same two principles in Nature, as to render the complete extrusion of the one necessary to the existence of the other? A few days ago, a Master of Arts, who is still a young man, and therefore the recipient of a modern education, stated to me that until he had reached the age of twenty years he had never been taught anything regarding Light, Heat, Magnetism, or Electricity: twelve years of his life previously had been spent among the ancients, all connexion being thus severed between him and natural phenomena. Now, we cannot, without prejudice to humanity, separate the present from the past. The nineteenth century strikes its roots into the centuries gone by, and draws nutriment from them. The world cannot afford to lose the record of any great deed or utterance; for such deeds and such utterances are prolific throughout all time. We cannot yield the companionship of our loftier brothers of antiquity—of our Socrates and Cato—whose lives provoke us to sympathetic greatness across the interval of two thousand years. As long as the ancient languages are the means of access to the ancient mind, they must ever be of priceless value to humanity; but it is as the avenues of ancient thought, and not as the instrument of modern culture, that they are chiefly valuable to Man. Surely these avenues might be kept open without making such sacrifices as that above referred to universal. We have conquered and possessed ourselves of continents of land, concerning which antiquity knew nothing; and if new continents of thought reveal themselves to the exploring human spirit, shall we not possess them also? In these latter days, the study of Physics has given us glimpses of the methods of Nature which were quite hidden from the ancients, and it would be treason to the trust committed to us if we were to sacrifice the hopes and aspirations of the Present out of deference to the Past.

I dare say the bias of my own education manifests itself in a desire I always feel to seize upon every possible opportunity of checking my assumptions and conclusions by experience. I might, it is true, appeal directly to your own consciousness in proof of the tendency of the human mind to inquire into the phenomena presented to the senses; but I trust you will excuse me if, instead of doing this, I take advantage of the facts which have fallen in my own way through life, referring to your judgment to decide whether such facts are truly representative and general, and not merely individual and local. At an agricultural college in Hampshire, with which I was connected for some time, and which is now converted into a school for the general education of youth, a Society was formed among the boys, which met weekly for the purpose of reading reports and papers upon various subjects. The Society had its president and treasurer; and abstracts of its proceedings were published in a little monthly periodical issuing from the school press. One of the most remarkable features of these weekly meetings was that after the general business had been concluded each member of the Society enjoyed the right of asking questions on any subject on which he desired information. The questions were either written out previously in a book devoted to the purpose, or, if a question happened to suggest itself during the meeting, it was written upon a slip of paper and handed in to the secretary, who afterwards read all the questions aloud. A number of teachers were usually present, and they and the boys made a common stock of their wisdom in furnishing replies. As might be expected from an assemblage of eighty or ninety boys, varying from eighteen to eight years old, many extraordinary questions were proposed. To the eye which loves to detect in the tendencies of the young the instincts of humanity generally, such questions are not without a certain philosophic interest, and I have therefore thought it not derogatory to the present course of Lectures to copy a few of these questions, and to introduce them here. They run as follows:

What are the duties of the Astronomer Royal?

What is frost?

Why are thunder and lightning more frequent in summer than in winter?

What occasions falling stars?

What is the cause of the sensation called " pins and needles " ?

What is the cause of waterspouts ?

What is the cause of hiccup ?

If a towel be wetted with water, why does the wet portion becomes darker than before ?

What is meant by Lancashire witches ?

Does the dew rise or fall ?

What is the principle of the hydraulic press ?

Is there more oxygen in the air in summer than in winter ?

What are those rings which we see round the gas and sun ?

What is thunder ?

How is it that a black hat can be moved by forming round it a magnetic circle, while a white hat remains stationary ?

What is the cause of perspiration ?

Is it true that men were once monkeys ?

What is the difference between the *soul* and the *mind* ?

Is it contrary to the rules of Vegetarianism to eat eggs ?

In looking over these questions, which were wholly unprompted, and have been copied almost at random from the book already alluded to, we see that many of them are suggested directly by natural objects, and are not such merely as had an interest conferred on them by previous culture. Now the fact is beyond the boy's control, and so certainly is the desire to know its cause. The sole question then is, is this desire to be gratified or not ? Who created the fact ? Who implanted the desire ? Certainly not Man—and will any man undertake to place himself between the mind and the fact, and proclaim a divorce between them ? Take, for example, the case of the wetted towel, which at first sight appears to be one of the most unpromising questions in the list. Shall we tell the proposer to repress his curiosity, as the subject is improper for him to know, and thus interpose our wisdom to rescue the boy from the consequences of Nature's atrocity in implanting a desire which acts to his prejudice ? Or, recognizing the propriety of the question, how shall we answer it ? It is impossible to answer it without reference to the laws of optics—impossible to answer it without making the boy to some extent a natural philosopher. You may say that the effect is due to the reflection of light at the common surface of two media of different refractive indices. But this answer presupposes on the part of the boy a knowledge

of what reflection and refraction are, or reduces you to the necessity of explaining them. On looking more closely into the matter, we find that our wet towel belongs to a class of phenomena exhibited by tabasheer and hydrophane, which have long excited the interest of philosophers. These bodies are opaque when dry, but when dipped into water or beech-nut oil they become transparent. The towel is white for the same reason that snow is white, that foam is white, that pounded granite or glass is white, and that the salt we use at table is white. On quitting one medium and entering another, a portion of light is always reflected, but with this restriction, the media must possess different refractive indices. Thus, when we immerse glass in water, light is reflected from the common surface of both, and it is this light which enables us to see the glass. But take a transparent solid and immerse it in a liquid of the same refractive index as itself, it will immediately disappear. I remember once dropping the eyeball of an ox into water; it vanished as if by magic, with the exception of the crystalline lens, and the surprise was so great as to cause a bystander to suppose that the mass had been instantly dissolved. This, however, was not the case, and a comparison of the refractive index of the vitreous humour with that of water cleared up the whole matter. The indices were identical, and hence the light pursued its way through both bodies as if they formed one continuous mass. In the case of snow, powdered quartz, or salt, we have a transparent solid body mixed with air; at every transition from solid to air, or from air to solid, a portion of light is reflected; this takes place so often that the light is wholly intercepted, and thus from the mixture of two transparent bodies we obtain an opaque one. Now the case of the towel is precisely similar. The tissue is composed of semi-transparent vegetable fibres, with the interstices between them filled with air; repeated reflection takes place at the limiting surfaces of air and fibre, and hence the towel becomes opaque like snow or salt. But if we fill the interstices of the towel with water, we diminish the reflection; a portion of the light enters the mass, and the darkness of the towel is due to its increased transparency. Thus the hydrophane, tabasheer, the tracing paper used by engineers, and many other considerations of the highest scientific interest are involved in the simple inquiry of this unsuspecting little boy.

Again, take the question regarding the rising or falling of the dew—a question long agitated, and finally set at rest by the beautiful researches of Wells and Mélloni. I do not think that any boy of average intelligence will be satisfied with the simple answer that the dew falls. He will wish to learn how you know that it falls, and, if acquainted with the notions of the Middle Ages, may refer to the opinion of Father Laurus, that, if you fill a goose egg with the morning dew and expose it to the sun, it will rise like a balloon—a swan's egg being better for the experiment than a goose egg. It is impossible to give the boy a clear notion of the beautiful phenomenon to which his question refers, without first making him acquainted with the radiation and conduction of heat. Take, for example, a blade of grass, from which one of these orient pearls is depending. During the day the grass, and the earth beneath it, possess a certain amount of warmth imparted by the sun; during a serene night, heat is radiated from the surface of the grass into space, and to supply the loss there is a flow of heat from the interior portions of the blade towards its surface. Thus the surface loses heat by radiation, and gains heat by conduction. Now, in the case before us, the power of radiation is great, whereas the power of conduction is small; the consequence is that the blade loses more than it gains, and hence becomes more and more refrigerated. The light vapour floating around the surface so cooled is precipitated upon it, and there accumulates to form the little pearly globe which we call a dewdrop.

Thus the boy finds the simple and homely fact which addressed his senses to be the outcome and flower of the deepest laws. The fact becomes, in a measure, sanctified as an object of thought, and invested for him with a beauty for evermore. He thus learns that things which, at first sight, seem to stand isolated and without apparent brotherhood in Nature are united by their causes, and finds the detection of these analogies a source of perpetual delight. To enlist pleasure on the side of intellectual performance is a point of the utmost importance; for the exercise of the mind, like that of the body, depends for its value upon the spirit in which it is accomplished. Every physician knows that something more than mere mechanical motion is comprehended under the idea of healthful exercise—that, indeed, being most healthful which makes us forget all

ulterior ends in the mere enjoyment of it. What, for example, could be substituted for the jubilant shout of the playground, where the boy plays for the mere love of playing, and without reference to physiological laws; while kindly Nature accomplishes her ends unconsciously, and makes his very indifference beneficial to him. You may have more systematic motions, you may devise means for the more perfect traction of each particular muscle, but you cannot create the joy and gladness of the game, and where these are absent, the charm and the health of the exercise are gone. The case is similar with mental education: but the extent to which this has been, and continues to be forgotten, would justify us in doubting whether Nature is so sparing of her gifts as to cause those souls which mark epochs in human history to be separated from each other by centuries, or whether the fact be not attributable to human mismanagement, by which the gifts referred to are squandered and misapplied. Why should the mind of youth be so completely warped from its healthful and happy action, so utterly withdrawn from those studies to which its earliest tendencies point, and in the cultivation of which the concurrence of its ardour would powerfully tend to the augmentation of its strength, as to leave the man in after-life, unless enlightened by his visits to an institution such as that in which we are now assembled, in absolute ignorance as to whether the material world is governed by law or chance, or indeed whether those phenomena which excited his youthful questionings be not really the jugglery of Scandinavian Jotuns, or some similar demonic power?

The study of Physics, as already intimated, consists of two processes, which are complementary to each other—the tracing of facts to their causes, and the logical advance from the cause to the fact. In the former process, called *induction*, certain moral qualities come into play. It requires patient industry, and an humble and conscientious acceptance of what Nature reveals. The first condition of success is an honest receptivity and a willingness to abandon all preconceived notions, however cherished, if they be found to contradict the truth. Believe me, a self-renunciation which has something noble in it, and of which the world never hears, is often enacted in the private experience of the true votary of science. And if a man be not

capable of this self-renunciation—this loyal surrender of himself to Nature, he lacks, in my opinion, the first mark of a true philosopher. Thus the earnest prosecutor of science, who does not work with the idea of producing a sensation in the world, who loves the truth better than the transitory blaze of to-day's fame, who comes to his task with a single eye, finds in that task an indirect means of the highest moral culture. And although the virtue of the act depends upon its privacy, this sacrifice of self, this upright determination to accept the truth, no matter how it may present itself—even at the hands of a scientific foe, if necessary—carries with it its own reward. When prejudice is put under foot and the stains of personal bias have been washed away—when a man consents to lay aside his vanity and to become Nature's organ—his elevation is the instant consequence of his humility. I should not wonder if my remarks provoked a smile, for they seem to indicate that I regard the man of science as an heroic, if not indeed an angelic, individual; and cases may occur to you which seem to indicate the reverse. You may point to the quarrels of scientific men, to their struggles for priority, to that unpleasant egotism which screams around its little property of discovery like a scared plover about its young. I will not deny all this; but let it be set down to its proper account, to the weakness—or, if you will—to the selfishness of Man, but not to the charge of Physical Science.

The second process in physical investigation is *deduction*, or the advance of the mind from fixed principles to the conclusions which flow from them. The rules of logic are the formal statement of this process, which, however, was practised by every healthy mind before ever such rules were written. In the study of Physics, induction and deduction are perpetually married to each other. The man observes, strips facts of their peculiarities of form, and tries to unite them by their essences; having effected this, he at once deduces, and thus checks his induction. Here the grand difference between the methods at present followed, and those of the ancients, becomes manifest. They were one-sided in these matters: they omitted the process of induction, and substituted conjecture for observation. They do not seem to have possessed sufficient patience to watch the slow processes of Nature, and to make themselves acquainted

with the conditions under which she operates. They could never, therefore, fulfil the mission of Man given at the commencement, "Replenish the earth, and subdue it." The subjugation of Nature is only to be accomplished by the penetration of her secrets and the mastery of her laws. This not only enables us to turn her forces against each other, so as to protect ourselves from their hostile action, but makes them our slaves. By the study of Physics we have indeed opened to us treasuries of power of which antiquity never dreamed: we lord it over Matter, and in so doing have become better acquainted with the laws of Mind; for to the mental philosopher the study of Physics furnishes a screen against which the human spirit projects its own image, and thus becomes capable of self-inspection.

Thus, then, as a means of intellectual culture, the study of Physics exercises and sharpens observation: it brings the most exhaustive logic into play: it compares, abstracts, and generalizes, and provides a mental scenery admirably suited to the conducting of these processes. The strictest precision of thought is everywhere enforced, and prudence, foresight, and sagacity are demanded. By its appeals to experiment, it continually checks itself, and thus walks on a foundation of facts. Hence the exercise it invokes does not end in a mere game of intellectual gymnastics, such as the ancients delighted in, but tends to the mastery of natural agents. This gradual conquest of the external world, and the consciousness of augmented strength which accompanies it, render the study of Physics as delightful as it is important. Its effects upon the imagination I have not observed closely, but certain it is that the cool results of physical induction furnish conceptions which transcend most of those of imagination proper. Take, for example, the idea of an all-pervading ether which transmits a tingle, so to speak, to the finger-ends of the universe every time a street lamp is lighted. The little billows of this ether can be measured with the same ease and certainty as that with which an engineer measures a base and two angles, and from these finds the distance across the Thames. Now there is just as much poetry in the measurement of the river as in that of an ethereal undulation; for the intellect, during the acts of measurement and calculation, destroys those notions of size

which appeal to the poetic faculty. It is a mistake to suppose, with Dr. Young, that

"An undevout astronomer is mad;"

there being no necessary connexion between a devout state of mind and the observations and calculations of a practical astronomer. For it is not until the man withdraws from his calculation, as a painter from his work, and thus realizes the great idea at which he has been engaged, that imagination and wonder are excited. Now here, I confess, is a possible danger. If the arithmetical processes of science be too exclusively pursued, they may, I think, impair the imagination, and thus the study of Physics is open to the same objection as philological, theological, or political studies, when carried to excess. But even in this case, the injury done is to the investigator himself: it does not reach the mass of mankind. Indeed the conceptions furnished by his cold unimaginative reckonings may furnish themes for the poet, and excite in the highest degree that sentiment of wonder which, notwithstanding all its foolish vagaries, table-turning included, I, for my part, should be sorry to see banished from the world.

I have thus far dwelt upon the study of Physics as an agent of intellectual culture; but like other things in Nature, this study subserves more than a single end. The colours of the clouds delight the eye, and, no doubt, accomplish moral purposes also, but the selfsame clouds hold within their fleeces the moisture by which our fields are rendered fruitful. The sunbeams excite our interest and invite our investigation; but they also extend their beneficent influences to our fruits and corn, and thus accomplish, not only intellectual ends, but minister, at the same time, to our material necessities. And so it is with scientific research. While the love of science is a sufficient incentive to the pursuit of science, and the investigator, in the prosecution of his inquiries, is raised above all material considerations, the results of his labours may exercise a potent influence upon the physical condition of Man. This is the arrangement of Nature, and not that of the scientific investigator himself; for he usually pursues his object without regard to its practical applications. And let him who is dazzled by such applications—who sees in the steam-engine and the electric

telegraph the highest embodiment of human genius and the only legitimate object of scientific research—beware of prescribing conditions to the investigator. Let him beware of attempting to substitute for that simple love with which the votary of science pursues his task, the calculations of what he is pleased to call utility. The professed utilitarian is unfortunately, in most cases, the very last man to see the occult sources from which useful results are derived. He admires the flower, but is totally ignorant of the conditions of its growth. The scientific man must approach Nature in his own way; for if you invade his freedom by your so-called practical considerations, it may be at the expense of those qualities on which his success as a discoverer depends. Let the self-styled practical man look to those from the fecundity of whose thought he and thousands like him have sprung into existence. Were they inspired in their first inquiries by the calculations of utility? Not one of them. They were often forced to live low and lie hard, and to seek a compensation for their penury in the delight which their favourite pursuits afforded them. In the words of one well qualified to speak upon this subject, "I say not merely look at the pittance of men like John Dalton, or the voluntary starvation of the late Graff; but compare what is considered as competency or affluence by your Faradays, Liebigs, and Herschels with the expected results of a life of successful commercial enterprise: then compare the amount of mind put forth, the work done for society in either case, and you will be constrained to allow that the former belong to a class of workers who, properly speaking, are not paid, and cannot be paid for their work, as indeed it is of a sort to which no payment could stimulate."

But while the scientific investigator, who, standing upon the frontiers of human knowledge, and aiming at the conquest of fresh soil from the surrounding region of the unknown, makes the *discovery* of truth his exclusive object for the time, he cannot but feel the deepest interest in the practical application of the truth discovered. There is something ennobling in the triumph of Mind over Matter: apart even from its uses to society, there is something sublime in the idea of Man having tamed that wild force which rushes through the telegraphic wire, and made it the minister of his will. Our attainments in

these directions appear to be commensurate with our needs. We had already subdued horse and mule, and obtained from them all the service which it was in their power to render: we must either stand still or find more potent agents to execute our purposes. To stand still, however, was not in the plan of Him who made motion a condition of life, and, as if by His high arrangement, the steam-engine appeared. Remember that these are but new things; that it is not long since we struck into the scientific methods which have produced these extraordinary results. We cannot for an instant regard them as the final achievements of Science, but rather as an earnest of what she is yet to do. They mark our first great advances upon the dominion of Nature. Animal strength fails, but here are the forces which hold the world together, and the instincts and successes of Man assure him that these forces are his when he is wise enough to command them. Is it not an object worthy the contemplation of a philosopher, to see a man experimenting in a corner, pondering in a closet, and gathering, by slow degrees, the mighty agencies of Nature into the sphericity of his little head: to see him come forth, and, in the application of his private thought, realize morally the physical dream of Archimedes, by lifting at an effort the whole world to a higher level. This has been done, and will probably be done again; but the study of Physics always was, and ever must remain, the forerunner of such achievements.

In the title of this Lecture, the study of Physics as a branch of education "for all classes" is spoken of. I am not quite sure that I understand the meaning intended to be conveyed by the words "all classes"; and I have regarded the question with reference to those mental qualities which God has distributed without reference to class. As an instrument of intellectual culture, the study of Physics is profitable to all: as bearing upon special functions, its value, though not so great, is still more tangible. Why, for example, should Members of Parliament be ignorant of the subjects concerning which they are called upon to legislate? In this land of practical physics, why should they be unable to form an independent opinion upon a physical question? Why should the senator be left at the mercy of interested disputants when a scientific question is discussed, until he deems the nap a blessing which rescues him

from the bewilderments of the committee-room? The education which does not supply the want here referred to, fails in its duty to England. I state nothing visionary, when I say that in a country like ours, whose greatness depends so much upon the applications of physical science, it would be a wholesome and rational test to make admission to the House of Commons contingent on a knowledge of the principles of Natural Philosophy. With regard to our working people, in the ordinary sense of the term working, the study of Physics would, I imagine, be profitable, not only as a means of mental culture, but also as a moral influence to woo these people from pursuits which now degrade them. A man's reformation oftener depends upon the indirect, than upon the direct action of the will. The will must be exerted in the choice of employment which shall break the force of temptation by erecting a barrier against it. The drunkard, for example, is in a perilous condition if he content himself merely with saying, or swearing, that he will avoid strong drink. His thoughts, if not attracted by another force, will revert to the public-house, and to rescue him permanently from this, you must give him an equivalent. It would certainly be worth experiment to try what the study of Physics would do here. By investing the objects of hourly intercourse with an interest which prompts reflection, new enjoyments would be opened to the working man, and every one of these would be a point of force to protect him against temptation. Besides this, our factories and our foundries present an extensive field of observation, and were those who work in them rendered capable, by previous culture, of appreciating what they see, the results to science would be incalculable. Who can say what intellectual Samsons are at the present moment toiling with closed eyes in the mills and forges of Manchester and Birmingham? Grant these Samsons sight, give them some knowledge of Physics, and you multiply the chances of discovery, and with them the prospects of national advancement. In our multitudinous technical operations we are constantly playing with forces where our ignorance is often the cause of our destruction. There are agencies at work in a locomotive of which the maker of it probably never dreamed, but which nevertheless may be sufficient to convert it into an engine of death. Again, when we reflect on the intellectual

condition of the people who work in our coal mines, those terrific explosions which occur from time to time need not astonish us. If these men possessed sufficient physical knowledge, I doubt not, from the operatives themselves would emanate a system by which these shocking accidents might be effectually avoided. If they possessed the knowledge, their personal interests would furnish the necessary stimulus to its practical application, and thus two ends would be served at the same time—the elevation of the men and the diminution of the calamity.

Before the present Course of Lectures was publicly announced, I had many misgivings as to the propriety of my taking a part in them. I felt that my place might be better filled by an older man, whose experience would be more entitled to respect. Small as my experience was, however, I resolved to adhere to it, and in what I have said regarding mental processes, I have described things as they reveal themselves to my own eyes, and have been enacted in my own limited practice. In doing this, I have been supported by the belief that there is one mind common to us all; and that if I be true to the expression of this mind, even in a small particular, the truth will attest itself by a response in the convictions of my hearers. There may be the same difference between the utterance of two individuals of different ranges of intellectual power and experience on a subject like the present, as between *The Descent from the Cross*, by Rubens, and the portrait of a spaniel dog. Nevertheless, if the portrait of the spaniel be true to nature, it recommends itself as truth to the human mind, and excites, in some degree, the interest that truth ever inspires. Thus far I have endeavoured to keep all tints and features which really do not belong to the portrait of my spaniel, apart from it, and I ask your permission to proceed a little further in the same manner, and to refer to a fact or two in addition to those already cited, which presented themselves to my notice during my brief career as a teacher in the establishment already alluded to. The facts, though extremely humble, and deviating in some slight degree from the strict subject of the present discourse, may yet serve to illustrate an educational principle.

One of the duties which fell to my share, during the period to which I have referred, was the instruction of a class in mathe-

matics, and I usually found that Euclid and the ancient geometry generally, when addressed to the understanding, formed a very attractive study for youth. But it was my habitual practice to withdraw the boys from the routine of the book, and to appeal to their self-power in the treatment of questions not comprehended in that routine. At first the change from the beaten track usually excited a little aversion: the youth felt like a child amid strangers; but in no single instance have I found this aversion to continue. When utterly disheartened, I have encouraged the boy by that anecdote of Newton, where he attributes the difference between him and other men mainly to his own patience; or of Mirabeau, when he ordered his servant, who had stated something to be impossible, never to use that stupid word again. Thus cheered, he has returned to his task with a smile, which perhaps had something of doubt in it, but which, nevertheless, evinced a resolution to try again. I have seen the boy's eye brighten, and, at length, with a pleasure of which the ecstasy of Archimedes was but a simple expansion, heard him exclaim, "I have it, sir." The consciousness of self-power, thus awakened, was of immense value; and, animated by it, the progress of the class was truly astonishing. It was often my custom to give the boys their choice of pursuing their propositions in the book, or of trying their strength at others not to be found there. Never in a single instance have I known the book to be chosen. I was ever ready to assist when I deemed help needful, but my offers of assistance were habitually declined. The boys had tasted the sweets of intellectual conquest and demanded victories of their own. I have seen their diagrams scratched on the walls, cut into the beams upon the playground, and numberless other illustrations of the living interest they took in the subject. For my own part, as far as experience in teaching goes, I was a mere fledgling: I knew nothing of the rules of pedagogics, as the Germans name it; but I adhered to the spirit indicated at the commencement of this discourse, and endeavoured to make geometry a *means* and not a *branch* of education. The experiment was successful, and some of the most delightful hours of my existence have been spent in marking the vigorous and cheerful expansion of mental power, when appealed to in the manner I have described.

And then again, the pleasure we all experienced was enhanced when we applied our mathematical knowledge to the solution of physical problems. Many objects of hourly contact had thus a new interest and significance imparted to them. The swing, the see-saw, the tension of the giant-stride ropes, the fall and rebound of the football, the advantage of a small boy over a large one when turning short, particularly in slippery weather; all became subjects of investigation. Supposing a lady to stand before a looking-glass of the same height as herself, it was required to know how much of the glass was really useful to the lady? and we learned, with great pleasure, the economic fact that she might dispense with the lower half and see her whole figure notwithstanding. It was also very pleasant to prove the angular velocity of a reflected beam to be twice that of the mirror which reflects it; we also felt deep interest in ascertaining from the hum of a bee the number of times the little insect flaps its wings in a second. Following up our researches upon the pendulum, we were interested to learn how Colonel Sabine had made it the means of determining the figure of the earth; and we were also startled by the inference which the pendulum enabled us to draw, that if the diurnal velocity of the earth were seventeen times its present amount, the centrifugal force at the equator would be precisely equal to the force of gravitation, and hence an inhabitant of those regions would have the same tendency to fall upwards as downwards. All these things were sources of wonder and delight to us: we could not but admire the perseverance of Man which had accomplished so much; and then when we remembered that we were gifted with the same powers, and had the same great field to work in, our hopes arose that at some future day we might possibly push the subject a little further, and add our own victories to the conquests already won.

I know I ought to apologize to you for dwelling so long upon this subject. But the days I spent among these youthful philosophers made a deep impression on me. I learned among them something of myself and of human nature, and obtained some notion of a teacher's vocation. If there be one profession in England of paramount importance, I believe it to be that of the schoolmaster; and if there be a position where selfishness and incompetence do most serious mischief, by lowering the

moral tone and exciting contempt and cunning where reverence and noble truthfulness ought to be the feelings evoked, it is that of the governor of a school. When a man of enlarged heart and mind comes among boys—when he allows his being to stream through them, and observes the operation of his own character evidenced in the elevation of theirs—it would be idle to talk of the position of such a man being honourable. It is a blessed position. The man is a blessing to himself and to all around him. Such men, I believe, are to be found in England, and it behoves those who busy themselves with the mechanics of education at the present day, to seek them out. For no matter what means of culture may be chosen, whether physical or philological, success must ever mainly depend upon the amount of life, love, and earnestness which the teacher himself brings with him to his vocation.*

* The following extract from a journal is, I think, too good to be omitted here. The writer of it—a pupil of Dirichlet and Steiner—would doubtless have felt himself more at home in dealing with elliptic functions than with the definitions of Euclid. But the manner in which he contrived to render the latter mysteries evident to a light-headed little boy, does credit to another faculty than his mere mathematical one, and will, I trust, prove as pleasant to the reader as it has to me. "K—— stammers distressingly, and this has impeded his progress very much. I have often passed him in the class, knowing that I could not get any intelligible answer from him, and had it not been for his eloquent eyes, which said, 'I know it, Sir, if I could but speak,' I might have mistaken him for a dunce, and thus done him great injustice. Through his love of mischief, however, and his inability to cope with his schoolfellows, on account of his defective utterance, it was evident that he was losing interest in his work, or rather that he had never felt much interest in it, and it became necessary to awaken him. One day, after he had been more noisy and mischievous than usual, I told him rather sternly to put on his cap and follow me. He did so, and I walked forward, while he, in a state of anxious suspense, walked behind me. After some moments' silence. I asked, 'Do you know, K——, what I am going to do with you?' 'Ne-ne-ne—no, Sir,' he replied. 'Well,' I said, 'I will tell you. I have spoken to you often enough, to no purpose, and now I intend to make you do better for the future.' We walked forward for some distance, and at length, putting my arm quietly around his neck, I broke silence once more. 'Can you tell me what an angle is, my boy?' 'Ye—ye—ye—yes, Sir, an angle is a—a—a—a—,' he could get no further, and turned his eyes upon me beseechingly. 'Well,' I replied to this silent appeal, 'go and pull two stalks of grass, and show me what an angle is.' This he did, and with the grass stalks continued to answer my questions on the geometrical definitions. We turned into a stubble field—by this time he had lost all fear, and could speak quite distinctly—'What is a right angled triangle?' I asked. 'It has all its angles right angles, Sir.' 'Indeed,' I replied, taking my arm from around his neck, 'it has three right angles, has it? Will you just kneel down?' He saw his mistake, stammered 'two,' looked at me piteously and hesitated. 'On your knees, Sir,' I cried, and he knelt down, while I, falling on my knees beside him, said, 'Now pull up some stubble, and make me a triangle having either two or three right angles.' At

Such are some of the thoughts which have floated before me, in a more or less distracted manner, in reference to the present hour; and nobody can be more conscious of their manifold imperfections than I am myself. Apart from other disadvantages, I have had the pressure of various duties interfering with the revival of my consciousness upon these matters, and thus preventing me from making the discourse as true a record of my own experience as I could wish it to be. I have throughout been less anxious to make out a case for Physics than to state the truth; and I confess that the Lecture of this day week causes me to doubt whether you are not entitled to expect from me a more emphatic statement of the claims of the science which I now represent than that which I have laid before you. When I saw your Lecturer reduced to the necessity of pleading for science, and meekly claiming for it, from the Institution which we are accustomed to regard as the highest in this land, a recognition equal to that accorded to philology, I confess that the effect on me was to excite a certain revolutionary tendency in a mind which is usually tranquil almost to apathy in these matters. Science behind Philology! The knowledge of the laws by which God's universe is sustained, and the perpetual advancement of humanity secured, inferior to that of the manner in which ancient and savage tribes put their syllables together, and express the varieties of mood, tense, and case! As the pole of a magnet acting upon soft iron induces in the latter a condition opposed to its own, so the irrationality of those who cast this slight upon Science tends, no doubt, to excite an opposite error on the part of their antagonists, and to cause them, in retaliation, to underrate the real merits of Philology. But is there no mind in England large enough to see the value of both, and to secure for each of them fair play? Oh! let us not make this a fight of partisans —let the gleaned wealth of antiquity be showered into the open breast; but while we "unsphere the spirit of Plato" and listen

once he saw his error, and the absurdity of our position, as we knelt together, making geometrical diagrams with stubble. Springing to his feet, he shook with laughter—'It has only one right angle, Sir—only one, of course!' I responded, 'Of course.' With my arm round his neck, we turned homewards, and continued our lesson successfully. 'This is the punishment I had in store for you,' I said, when we reached home. 'Now go, and transgress no more,' to which his eyes responded, 'I will, Sir.'"

with delight to the lordly music of the past, let us honour by adequate recognition the genius of our own time. Let me again remind you that the claims of that science which finds in me to-day its unripened advocate, are the claims of God's workmanship upon the attention of His creatures, and that its exercises, as an agent of culture, are based upon the natural relations subsisting between Man and the world in which he dwells. Here, on the one side, we have the apparently lawless shifting of phenomena ; on the other side, mind, which requires law for its equilibrium, and in obedience to its own indestructible instincts, believes that these phenomena are reducible to law. To chasten this apparent chaos is a problem which man's Creator has set before him. The world was built in order : it is the visual record of the Creator's logic, and to us He has trusted the will and power to follow Him through this great argument. By the manifestations of Nature which He has ordained, He appeals to the faculties which He has implanted, and surrounds them from the cradle to the grave with objects which provoke them to inquiry. Descending for a moment from this high plea to considerations which lie closer to us as a nation—as a land of gas and furnaces, of steam and electricity : as a land which science, practically applied, has made great in peace and mighty in war :—I ask you whether this " land of old and just renown," which may God keep unimpaired, has not a right to expect from her institutions a culture more in accordance with her present needs than that supplied by declension and conjugation ? And if the tendency should be to lower the estimate of science, by regarding it exclusively as the instrument of material prosperity, let it be their high mission to furnish the proper counterpoise by pointing out its nobler uses, and lifting the national mind to the contemplation of it as the last development of that " increasing purpose " which runs through the ages and widens the thoughts of men.

ON THE IMPORTANCE OF THE STUDY OF PHYSIOLOGY AS A BRANCH OF EDUCATION FOR ALL CLASSES

A LECTURE DELIVERED AT THE ROYAL INSTITUTION OF GREAT BRITAIN

By JAMES PAGET, F.R.S.
Assistant-Surgeon and Lecturer on Physiology at St. Bartholomew's Hospital

It is my office to submit to you the importance of the study of physiology as a branch of education for all classes; to state the grounds on which it seems desirable that every one should learn somewhat of the structure of the human body, and of the processes that are carried on within it, and the laws according to which they are governed.

The advantages to be expected from the general teaching of physiology may be grouped in two classes: the first, including such as would tend to the promotion of the science: the second, such as would belong to the students.

By a wider diffusion of the knowledge of physiology its progress would be accelerated, as that of any other science would, by the increased number of the competent observers of its facts.

But a larger advantage, and one which, I think, physiology needs more than any other science does, would arise in this; that the communication would be easier, which is now so difficult, between those who are engaged in it, and those who specially devote themselves to other sciences that might assist it. Almost every process in the living body involves the exercise of mechanical and chemical—perhaps, also, of electrical—forces, whose effects are mingled with those of the more proper vital force; and although this special force may modify, and in some sort veil, the effects of the others, yet must their

influence be reckoned and allowed for in nearly every case we have to study. Therefore the complete solution of any new physiological problem must require such a master of all these sciences of dead and living matter as cannot now, I believe, be found, or else it must have the co-operation of many workers, each skilled in some single science, and able to communicate with all the rest. Such co-operation is, through the present narrowness of teaching, almost impossible. The mere chemist, or mechanical or electrical philosopher, and the mere physiologist (one, I mean, who studies it chiefly by anatomy or by direct experiment), can scarcely so much as understand each other's language: they work apart at the same subject; and sometimes even confuse each other, by showing the same facts in different lights, and explained in different and mutually unintelligible terms. I know well that it requires nearly all the power of a strong mind so to master any of the physical sciences as to be able to investigate its applications in the living body; and that, therefore, few could hope to be at once excellent in physiology and in any science of dead matter; but the co-operation that I speak of would not need more than that the skilled workman in each science should understand the language, and the chief principles, and modes of working, of the rest. I am sure that it is, in great measure, through the want of help, such as it might hence derive, that the onward steps of physiology are so slow, so retarded by backslidings, and by the consciousness of insecurity.

And in yet another way I believe that the general teaching of physiology would insure its more rapid progress —namely, by finding out those who are especially fit for its study.

If we mark the peculiar fitness of certain men for special callings, who are even below an average ability in the common business of life, one might imagine some natural design of mutual adaptation between things to be done and men to do them; and certainly, it were to be wished that a wider scheme of education should leave it less to chance whether a man will fall, or fail to fall, in the way of that special work for which he seems designed. Really, it has seemed like a chance that has led nearly every one of our best physiologists to his appropriate work: like a chance, the loss of which might have consigned

him to a life of failures, or of mediocrity, in some occupation for which he had neither capacity nor love.

Such are some of the chief benefits that might result to physiology if it were more generally studied. I might tell of more; but I will not do so, nor enlarge on these; for it might be argued that it would be unjust to tax every one with intellectual labour for the advancement of one science, even though that science be the foundation of the healing art, in whose improvement every one is interested. I will rather try to show that, through such labour in the study of physiology, every one would gain for himself some more direct advantage.

I believe that even a moderate acquaintance with the principles of physiology, acquired in early life, would benefit a man, with regard to both his body and his mind: and that it would do this by guiding him in the maintenance and improvement of health, by teaching him the true economy of his powers, whether mental or corporeal, by providing worthy materials for thought, and by cultivating peculiar modes, and suggesting peculiar ends, of thinking.

But before I attempt to illustrate these things, let me meet an objection which is likely to be made against any proposal that physiology should be a subject of general education—namely, that it cannot be generally taught, because (it is supposed) its objects are difficult to show, and it requires dissections and painful experiments for its illustration.

To such objections the answer is easy: that the rudiments of physiology are taught already, largely and efficiently, in several schools of both England and Scotland. For such instruction, no general practice of dissection or of experiments is at all necessary. For most of the illustrations, drawings would suffice; especially such as those which have been constructed with admirable art, and published for the use of schools, under the direction of Mr. Marshall, of University College, for the Board of Trade Department of Science. Other things could be well taught with models.* The organs of animals might, in some instances, be used; and dried specimens. Only let there be a demand for the materials of such

* Specimens were shown of models of the development of the chick, very accurately executed in wax, from nature, by Mr. Tuson.

teaching, and I will venture to promise that modern art, such as these examples display, will soon supply them at no great cost, and without offence to the most refined feelings.

But while I speak of what modern art would do, I am bound to add that the teaching of physiology, not by representations, but by the very objects of its study, was long ago sanctioned by the highest and most venerated authority in the land. For, in the Museum of the College of Surgeons, there are now several beautiful specimens of the chief organs of the human body, prepared by John Hunter, which formed part of a collection, made at Kew, by His Majesty King George III, for the instruction of the princes, his sons.

But if it be admitted that physiology can be generally taught, yet some may say that, so far as the improvement of health and the economy of power are concerned, such teaching is unnecessary; for that, to these ends, a man need only follow the guidance of nature and of instinct. And, indeed, at first thought, it may seem very strange that we should want instruction for keeping ourselves in health; strange that man should be left with no natural true guidance to so great a good: that man alone, for whom the earth seems made, should need mental labour to preserve or recover bodily health. Yet so it is: for none of our untaught faculties, neither our senses nor our instincts, are sufficient guides to good or guards from evil, in even the ordinary conditions of civilized life.

The acuteness of our senses is not at all proportionate to the vital importance of the things that we observe with them. They are unable to discern the properties, or even the presence, of some of the most deadly agents. For example, we have a far keener sense of the temperature of the atmosphere than of its composition, or fitness for breathing. yet the ordinary changes in its temperature concern little more than our comfort; those in its composition may affect our life. And thus it is that, seeking only the comfort of warmth, which their senses can discern, men will breathe atmospheres laden with noxious gases, which they can scarcely detect till they have accumulated to the peril of their lives.

So with food: we have a keener sense of hunger and thirst than of the sufficiency or fitness of our foods. We can at once appreciate their flavour, but not their nutritive value; and

those we most affect are not always the most appropriate to our state.

Our instincts avail us scarcely more. After childhood, in civilized life, the instincts are almost in abeyance, and the intellect and instruction have a share in the most ordinary acts of life. The sensations of thirst and hunger impel us instinctively to seek their satisfaction; and by instinct we know how to do so; but in doing it, we drink in adaptation to instruments of intellectual invention; and we eat things intellectually cooked, with apparatus of intellectual art: yes, intellectual, for the meanest piece of cookery requires that control and management of fire, which no mind lower than the human intellect has ever reached, and the possession of which might alone suffice to prove man's primacy among all the creatures of the earth.

But I need not multiply instances (I will not say of the inutility, but) of the insufficiency of our untaught powers for our guidance, in the commonest things of civilized life, relating to our health. Every one has suffered from following what has seemed some natural guidance, and has learned that we only gradually attain some knowledge of these things by experience or education; i.e. by the exercise of the understanding as well as of the senses.

If it be asked whether a state of ignorance regarding his own health be natural to man, I must answer that I suppose Providence has taken ample care for his good, in all those things which are of natural ordinance and independent of his will: but that, for those conditions which he generates or incurs by his own power and free-will, he is left by the same power to provide. I suppose that men may, generally, be, like other creatures, aware, by sense or instinct, of those things which are for their good, when the simplest conditions of their existence are undisturbed. But these are not the conditions in which we live. Men have disturbed, in successive generations, almost every simple and original condition of their existence. In every generation they have been striving, with intellectual labour, to add to the comforts and luxuries of life, to their control of the forces, and their independence of the ordinary course, of nature. And many of their successes in this strife, being achieved by the disturbance of some natural and fit condition of mere subsistence, have almost necessarily incurred some

consequent evils, which have marred, though they may not have neutralized, the good, and have gradually accumulated to our damage.

If, indeed, in all the improvements of our means of life, only half the trouble had been taken to prevent or remedy the future evil that was taken to attain the present good, our state might have been far different. If, for examples, men had been as anxious to invent the means of destroying coal-smoke, as to gain the myriad benefits of coal-fires; if they had thought as much and as soon of constructing drains below the ground, as of building above it; as much even of clearing out the refuse of our gas-lights, as of tempering and diffusing their brilliancy for comfortable use;—then we might have gained unalloyed benefits from every such disturbance of the natural conditions of life: the vast catalogue of diseases appertaining to our social state might have been unwritten; and that which one age hailed as a national blessing might not have entailed upon the next a national calamity. But this has not been done; and thus, from age to age, the evil residues of good things have accumulated; the good still, happily, preponderating, but the evils such as every man, and every society of men, have now to guard against, and such as can be averted or counteracted with no other human power than that of the intellect instructed in the science of health.

Perhaps, now, the only question is, whether this instruction need be given to all, or whether it had not better be still left, as it is by present custom, to a few, to exercise it in a special profession. I cannot doubt that here, as in other cases, for all ordinary care, for all habitual management, each man should be fit to be his own guardian; while for emergencies, and the more unusual events, he should accept and be able to choose some more instructed guidance. It is not necessary, or likely, that every one who has learnt somewhat of the structure of his own body, and of the processes carried on in it, should seek to be his own doctor; not more so than that every one who has learnt the construction and principle of a steam-engine should be restless unless he be his own engineer. We need not fear a misuse, through excessive use, of such physiology as can be generally taught. Certainly, if I may speak as one of the medical profession, we see greater injury sustained through

ignorance than is likely to accrue to imperfect knowledge, whether it be the most timid or the most rash.

And here, when I speak of ignorance, I am obliged to say that I do not mean only the state of those who are wholly uneducated, but include the state of nearly all who have not received some special teaching. For, really, in regard to all that concerns our life and health, it seems as if no amount of general education, no clearness of apprehension for science or for the general business of life, were sufficient for security against the grossest errors. I will not speak of the follies (as I believe them to be), that are now regarded as truths, and even useful truths, by generally well-instructed, shrewd, and accomplished persons. I will only say that, at all times, such persons have been as ready as the most uneducated to believe and submit themselves to practices which the physiology even of their own times could prove to be gross and mischievous fallacies. In every age, it has been true that "the desire of health, like the desire of wealth, brings all intellects to the same level"; that is, all that have not some special wisdom in the art of health or of wealth.

If now it may be received that physiology should be generally studied for the sake of health, it may be asked what parts of it should be chiefly taught, and in what method? I might leave this to those who are occupied with general education, and with younger students than I have had to teach. But considering that the large majority of those to whom it would be taught are to be engaged, in after life, in pursuits alien from science, and that we therefore could not hope to do much more than leave general impressions such as might abide for general guidance, I feel nearly sure that the mere facts of physiology, and much more those of anatomy, should be taught in subordination to their general principles.

If I try to illustrate this by an example, I fear lest to some I seem almost unintelligible; for I have never before lectured except to students or members of my own profession, to whom I could use technical terms, and whom I could suppose to be, in some measure, already acquainted with my subject.

But, for an example, in relation to the economy of power, suppose of muscular power, and thereby in regard to the main-

tenance of health, it would have to be taught that, in the living body, the apparent stability and persistence of its structures is due, not to their being literally indestructible, but to the constant operation of a process in them by which the particles that decay, or are outworn in the exercise of their offices, are constantly removed, and replaced by new ones like themselves. We know that in all the actions of the body there is waste and impairment of the active parts. But though, day after day, we exert, even in the common acts of life, in walking, feeding, breathing, thinking, talking, great amounts of force, and though, with the use of force, there is always a proportionate consumption of the material of our bodies, yet, year after year (at least for many years), we appear to be and feel the same: because the consumption, the wear and tear, of material that occurs in the action of our several parts is constantly repaired in the intervals of rest.

Then, following out this principle, it might be shown that an economy of vital power is commonly maintained in the body by the just regulation of alternate periods of action and repose; and this might be taken as a principle for useful illustration.

The climax of the exercise of muscular power seems to be attained in the heart. Perhaps there is nothing, of equal weight, that exerts in the same time so large an amount of force as a heart does. In every second, or oftener, discharging blood from its cavities with a force equal to the lifting of a weight of from ten to fifteen pounds, it goes on hour after hour, and year after year, untired and almost unchanged. Now, by the similarity between the structure and mode of contraction of the muscular fibres of the heart, and those of the muscles over which we have control, we may be sure that its fibres are subject to the same impairment in their actions as theirs are known to be; and that they must need the same repair in rest as the voluntary muscles obtain in sleep. But the heart seems never to sleep; and we explain the secret of its apparently unceasing exercise of power by referring to its exact rhythm of alternating contractions and dilatations; by the fact that every contraction by which it forces blood into the vessels, i.e. every act which we can feel as a beat or throb, is succeeded by an interval of rest, or inaction, of the same length; and by the probability that in each period of inaction (brief as

it is) the changes that occurred during the contraction are repaired.

It is the same with the muscles for breathing, in their ordinary and involuntary exercise. The alternation of their action and repose is constant; and they too, though exerting forces that are truly enormous, neither waste nor weary themselves; because (we may hold) in every period of inaction they repair the changes wrought in them by their action.

Now the principle which is thus illustrated may probably be applied to nearly all muscular exertion. Whatever work is to be done, the largest amount of force may be utilized with the least injury when rest and action are made to be alternate. And this is to be observed, not only in that long rest which our voluntary muscles have in sleep, but, equally, in more active life; wherein more force is always obtained by the alternate action of certain groups of muscles than by the sustained action of any single group. Thus, I think, it can be proved that there are no voluntary actions in which the human body can exercise larger amounts of force than in ordinary progression, as in walking or in running. And it is because of the alternation of the similar acts done by the two halves of the body, and especially by the two lower extremities. For if you watch a man walking, you will see that each of his limbs is doing exactly the opposite to what the other is doing, and to what itself has just finished doing; and the corresponding muscles are never in the same action upon both sides at once: and so if one step has been made, say, chiefly, with the muscular effort of the right limb, the next will be made with a similar effort of the left, while the muscles of the right will have an interval of comparative inaction.

In some measure, therefore, the principle of alternate action and repose, typified in the case of the heart, is applied here. But it is not so completely observed; for we tire in walking, even while our hearts may be growing more active. This, however, is not only because of the motion, but because many muscles must be in almost constant exercise for the maintenance of the erect posture, and because, probably, in these voluntary exercises the rest of a muscle is never quite perfect, even in its relaxing state.

This same principle, of the economy of force in the alternation

of action and repose, is doubtless true of the nervous as of the muscular system; and on it we explain the need of repose, prolonged and deep, in direct proportion to the length and intensity of mental exercise. On the same principle we explain the refreshment of the mind by change of occupation or of the train of thought: so that, while one part of the brain is occupied, another may be at rest after its work is done. And many like things may be thus explained, which it would be well for all to know, but chiefly for those who have to teach, and who need to regulate their pupils' mental exercises with the best economy they can.

There is another class of organs in which the alternations of action and rest, of waste and repair, appear essential to the full exercise and economy of power. The stomach is one of these; and a knowledge of the method of its office of digestion might prevent somewhat of its almost universal misuse.

Its chief office in digestion is to produce a peculiar fluid which, mingling with the food, may, by a process similar to fermentation, reduce it to solution or to a state of extremely minute division. This fluid, the gastric or digestive fluid, does not merely ooze from the blood; but is so formed in minute cells that, for each minutest microscopic drop of it, a cell, of complex structure, must be developed, grow, and burst or be dissolved.

A diagram would very well show how the lining membrane of the stomach is formed, almost entirely, of minute tubes, set vertically in its thickness, like little flasks or test-tubes, close-packed and upright. The outer walls of these are webbed over with networks of most delicate blood-vessels, carrying streams of blood. Within, the same tubes contain cells, and those among them which chiefly secrete the digestive fluid are nearly filled with cells, which have taken materials from the blood, and from those materials have formed themselves and their contents. In what way they have done this, we cannot tell: but we can tell that the process is one of complicate though speedy development and growth; even such a process as that by which, more slowly, the body grows, or any of its parts—the hair or the nails, or any other that we can best watch. The act of secretion or production of this fluid is, literally, the growth and dissolution of the minute cells which, though they be very

short-lived, yet must need a certain time for their complete elaboration.

If this be so, it must follow that we cannot, with impunity, interfere with that which seems a natural rule, of allowing certain intervals between the several times of feeding. Every act of digestion involves the consumption of some of these cells: on every contact of food, some must quickly perfect themselves, and yield up their contents; and without doubt, the design of that periodical taking of food, which is natural to our race, is that, in the intervals, there may be time for the production of the cells that are to be consumed in the next succeeding acts of digestion. We can, indeed, state no constant rule as to the time required for such constructions: it probably varies according to age, and the kind of food, and the general activity or indolence of life, and, above all, according to habit; but it may be certainly held that when the times are set, they cannot, with impunity, be often interfered with; and, as certainly, that continual or irregular feeding is wholly contrary to the economy of the human stomach. And yet such constant feeding is a frequent custom—not infrequent among the adult rich, but most frequent among the infants of the poor, for whom food is the solace of every grief.

I would thus try to teach general principles of physiology; and with such principles there might easily be combined some useful rules for prudence in the ordinary management of personal or social health, and in the habitual exercise of power.

I will not venture to say that it is only by teaching physiology that prudence can be taught; for even in the cases I have cited, physiology teaches no other rule than nature and experience had already indicated. Still, even in regard to those rules, when it shows their reason and their meaning, it gives them strength, and it enlists the power of the understanding against the overbearing of inclination and bad habit. And so, though it might be impossible to teach more than a small part of the whole body of physiology, yet one who had learned even this part would have a better apprehension of the rest than one untaught could have. One who had learned the general mode of study, and the labour which is spent in ascertaining physiological truths, and the great probability that what is generally accepted is at least nearly true, would, more than an untaught

man, act on the advice of those who are instructed. Thus acting, he would, as a citizen, be no hinderer of improvements, no block of utter ignorance in the way of amending the sanitary condition of his fellows: with belief, if not with knowledge, he would give his help to good. And for his own guidance, such a one, though only partially instructed, would be a far better judge than most men are of the probable value of professed discoveries in medicine; he would be doubtful of all unreserved assertions; wisely incredulous of all results supposed to flow from apparently incompetent sources. Even the desire of health would bear frequent disappointment before it would induce him to commit himself to the daring promises of ignorance.

I have said that we might anticipate advantages to the mind, as well as to the bodily health, from making physiology a branch of general education. And some of these advantages must not be widely separated from those of which I have been speaking: for they are, in truth, closely correspondent, derived from the same source and by the same method. The health of the mind, so far as it is within our own control, is subject to the same laws as is the health of the body. For the brain, the organ of the mind, grows and is maintained according to the same method of nutrition as every other part of the body; it is supplied by the same blood; and through the blood, like every other part, may be affected for good or ill by the various physical influences to which it is exposed. But I will not dwell on this more than to assert, as safely deducible from physiology, that no scheme of instruction, or of legislation, can avail for the improvement of the human mind, which does not provide with equal care for the well-being of the human body. Deprive men of fresh air, and pure water, of the light of heaven, and of sufficient food and rest, and as surely as their bodies will become dwarfish, and pallid, and diseased, so surely will their minds degenerate in intellectual and moral power.

But let me suppose that these needs of the body may be happily within men's reach; and then I may speak of the advantages that would accrue from the general study of physiology, in the mental culture it would provide.

I again remind myself that the cases to be kept in view are

not only those of men who are to be chiefly occupied with science, but those of persons who are to pursue the various common businesses of life; and upon whose minds we cannot expect that those studies of their school-time, which would be widely different from the occupations of their later life, will do more than leave general impressions, and impart an habitual method and tone of thought. To such persons I believe that the study of physiology would be useful, first, on the general ground that they who can, with most force, apply themselves to any business in life (be it what it may) are those whose minds are disciplined and informed in all their parts, so as to be not only full and strong, but pliant, liberal, and adaptive.

Now, there are some characters in physiology by means of which its study might affect the mind, or certain parts of it, differently from any portions of even that enlarged education which it is the object of this whole course of lectures to recommend.

One of these is, that it is occupied with things of admitted incompleteness and uncertainty. In other, and especially in the physical, sciences, I think it is only the master, or the advanced student, who is impressed with their uncertainty. In them, speaking generally, that which is taught admits of clear proof; and imperfection is not spoken of, except, as it were, at the distant boundaries of a vast body of truth. But, in physiology, the teacher would need everywhere to mark the imperfections of his knowledge; in the very rudiments, he must speak of things as only, in various degrees, probable.

Some of my predecessors in this course have shown how much the value of the physical sciences lies in the possibility of proving what is held in them, and in the precision of the mental exercises which they thus demand and cultivate; and no one can be more conscious than I am that, on this account, they are indispensable elements of sound education. But I believe, also, that it would be right to mingle with this study that of a much more incomplete and uncertain science. I think it would be good, at least for some minds, to know in early life how much has yet to be done in science; so that some through ambition of discovery, some through love of enterprise, some through mere curiosity, might be excited to work among the stores of unexplored knowledge that would be pointed out to

them. It is strange how early, and how strong in early life, these ambitions of discovery and invention arise; and I suppose that, in all later life, there are no enjoyments more keen, or more invigorating to the mind, than those felt in boyhood, when such an ambition is gratified;—whether by the finding of some plant unknown before in the home-district, or by the invention of some new appliance to a toy, imitating what men deal with, or—it matters not by how trivial a thing. I would not venture to say how large a part such ambition should be allowed to have among the motives to study, but I think it should not be quite suppressed, or starved, as it is by teaching only such things as are already proved, or decided by authority.

And, perhaps, yet another advantage would flow from the teaching of physiology, honestly and expressly, as a very incomplete and uncertain science. It is a great hindrance to the progress of truth that some men will hold, with equal tenacity, things that are, and things that are not, proved; and even things that, from their very nature, do not admit of proof. They seem to think (and ordinary education might be pleaded as justifying the thought) that a plain "yes" or "no" can be answered to every question that can be plainly asked; and that everything thus answered is a settled thing, and to be maintained as a point of conscience. I need not adduce instances of this error, while its mischiefs are manifest everywhere in the wrongs done by premature and tenacious judgments.

I am aware that these are faults of the temper, not less than of the judgment; but we know how much the temper is influenced by the character of our studies; and I think if any one were to be free from this over-zeal of opinion, it should be one who is early instructed in an uncertain science, such as physiology. He might receive, with reverent submission, all revealed truth; he might bend unquestioning to the declarations of teachers authorized to promulgate positive commandments; but his habit of thinking how soon all inquiries concerning living things end in uncertainty, his experience of the exceeding difficulty of settling for ever even a small matter, would make him very scrupulous in accepting as completely proved, very slow in making a point of conscience of, anything

that may be made a matter of reasonable discussion or of further study.

Let me repeat that I do not hold that it is beneficial to study only or chiefly such a science as this, whose principles scarcely admit of full proof. I know too well the danger of resting satisfied with error, when truth cannot be quite attained. But I lecture only as one of many, advocating the importance of as many different branches of study; and I think that the early study of uncertainties might well be mingled with that of things which may be proved beyond all doubt.

But I have yet to speak of that through which, I believe, the general teaching of physiology would exercise the greatest influence upon the mind; namely, its being, essentially, a science of designs and final causes. In this (if we regard it in its full meaning, as the science concerning living things) it is chiefly in contrast with the physical sciences, and, so far as I know, with nearly all the other studies of even the widest scheme of education.

I do not say that it is only in living things that we can discern the evidences of design. Doubtless, things that are dead—things that we call inorganic, when we would distinguish them from living organisms—are yet purposive, and mutually adapted to co-operate in the fulfilment of design. We cannot doubt, for example, that all the parts of this dead earth, and all the members of our planetary system, are adapted to one another with mutual influence; balanced and laid out in appropriate weight and measure; fitted each to do its part, and serve its purpose, in some vast design. And thus the whole universe might be called an organism; constructed in parts and systems, almost infinite in number and variety, but adjusted with an all-pervading purpose. Still, there is a striking difference between dead and living things, in the degree and manner in which their laws and their designs are manifest to us. In the inorganic world, in the studies of the physical sciences, we seem to come nearer to the efficient, than to the final, causes of events: we discern, it may be, both the most general laws and the most minute details of the events; but these rarely shadow forth their purpose or design; or, if they do, it is a design in adaptation to organic life, as where we may trace the fitness of the earth and air for their living occupants.

But, in the inorganic world, the reverse is true: purpose, design, and mutual fitness are manifest wherever we can discern the structure or the actions of a part; utility and mutual dependence are implied in all the language, and sought in all the studies, of physiology. The efficient causes and the general laws of the vital actions may be hidden from the keenest search; but their final causes are often nearly certain. In the sciences of the inorganic world, we can learn *how* changes are accomplished, but we can rarely tell *why* they are: in those of the organic world, the question "why" can be often answered, the question "how" is generally an enigma that we cannot solve.

Now, were there no other argument for the general teaching of physiology, I would be content with this: that an education which does not include the teaching of some science of natural designs does not provide for the instruction of one of the best powers and aspirations of the mind.

The askings of children seem to indicate a natural desire after the knowledge of the purposes fulfilled in nature. "Why?" and "Of what use?" are the ends of half their untutored questions; and we may be sure they have not the wish for such knowledge without the power of attaining it, if the needful help be given them. And yet, in the usual subjects of education, nothing addresses itself to this desire, and so there is not only a neglect of the teaching of the peculiar modes of reasoning required, or admitted, in physiological research; but the natural love and capacity for studying design are left to spend themselves, untrained, upon unworthy objects; and so they fade or degenerate—degenerate, perhaps, into some such baseness as an impertinent curiosity about other men's matters.

I would therefore have physiology taught to all, as a study of God's designs and purposes achieved; as a science for which our natural desire after the knowledge of final causes seems to have been destined; a science in which that desire, though it were infinite, might be satisfied; and in which, as with perfect models of beneficence and wisdom, our own faculties of design may be instructed. I would not have its teaching limited to a bare declaration of the use and exact fitness of each part or organ of the body. This, indeed, should not be omitted; for there are noble truths in the simplest demonstrations of the

fitness of parts for their simplest purposes, and no study has been made more attractive than this by the ingenuity, the acuteness, and eloquence of its teachers. But I would go beyond this, and striving, as I said before, to teach general truths as well as the details of science, I would try to lead the mind to the contemplation of those *general* designs from which it might gather the best lessons for its own guidance.

If I may presume to speak as I would to boys or girls, I would say let us learn frugality from some of the designs that we can study in the living body; and surely the lesson may be the more impressive if we remember that we are studying the frugality of One whose power and materials are infinite.

Observe, for example, what happens during active exercise; how the heart beats quicker and harder than it did before, and the skin grows warmer and ruddier, and the blood moves faster, and the breathing is quicker. The main design of this seems to be that the active muscles may be the more abundantly supplied with blood. But the beginning in the series of changes is an instance of that designed frugality of which I have been speaking. Veins, carrying blood to the heart, lie, as you see, branching and communicating under the skin; and there are others like them deeper set among the muscles of both the limbs and the trunk. Now, muscles, when they act, shorten and swell up: and in so doing (as in active exercise) they compress the veins that lie between them, or upon them underneath the skin. The effect of such compression must be to press the blood in every vein, equally in both directions—both onwards towards the heart, and backwards from it. All that part of this pressure which is effective in propelling the blood towards the heart is so much added to the forces of the circulation; it is so much direct gain of force. But it may seem as if this gain were balanced by an equal loss, through the influence of the same pressure driving other portions of the blood backwards. And so it would be, but for the arrangement of valves in the veins, which are the instruments of this saving of force. Wherever there are muscles that in their action can compress the veins, there, also, the veins have valves; and a diagram or a model would show that these are little pocket-shaped membranes, which project into the canals of the veins in such a manner that they will allow the streams of blood to pass

onwards to the heart, but will close at once and hinder any stream that would flow backwards. Thus, therefore, the effect of muscular pressure on the veins is (let us say), with a certain force, to propel some blood towards the heart, and with the same force to press back other blood upon the valves and close them. You will say, then, here is still the same hindrance: if the valves be closed, the stream behind them must be stopped, and there is as much loss as gain. It would be so if there were not this other provision: that wherever there can be muscular pressure upon veins, those veins not only have valves, but have abundant channels of communication with one another. The back-pressure of the blood, and the closure of the valves, is therefore no hindrance to the circulation; for the blood that might be stopped in one vein makes its way at once into another by some communicating branch. The general result, therefore, is, that all muscular pressure upon veins is an almost unalloyed advantage to the circulation. And now mark the frugality of the design. Veins *must* lie in or near these places, and the muscles *must* act (suppose for some design of our own); and if they are to be in very active exercise, they will need swifter streams of blood than will suffice in their repose. The streams could be made swifter by a greater force of the heart; but heart-force is a thing to be economized; and the muscles themselves may, without harm, contribute to accelerate the blood; for in the fulfilment of their primary purpose, of moving and sustaining the limbs and trunk, they *must* swell up, and compress the veins that are about them; and this compression can be made effective for the circulation of the blood by the mechanism of valves. So then, in the necessary fulfilment of their primary use, and without the least hindrance or damage to it, the muscles are made to serve this secondary purpose; and all that they do herein is so much saved to the forces of the heart.

Scarcely a lesson in physiology could be given but it might illustrate some such design as this. Everywhere we see examples of parts thus made to serve by-purposes while fulfilling their primary designs.

I will mention but one more. All know that the air we have once breathed is less fit for breathing than it was before, and that if we breathe the same air often it becomes poisonous

through the mixture of the carbonic acid and other exhalations from the lungs. We must breathe out the air, therefore, as so much refuse; and ample provision is made that we may do so; and it might seem design enough fulfilled when we are thus freed from our own poison. But is it not an admirable secondary design, an admirable frugality, a true wisdom by the way, that, with this same air, we speak; that this, which we must cast out lest it destroy us, should be used for one of the noblest powers of man? Surely, one might have supposed, for so great a purpose as the communion of human thoughts, and for all that speech and vocal melody can achieve, there would be contrived some matchless instrument, some rare material. But no: the instruments of human speech are scarcely more complex organs than those which dumb creatures have to breathe and feed with; and the material for human speech carries out the refuse of the blood; the very dross of the body is used for the coinage of the mind.

Such might be some lessons in that Divine frugality which is ever "gathering up the fragments that remain, that nothing be lost." The moral of such lessons is very plain.

Not less significant are those which may be studied in the designs of the body during its development. All these are instances of present things having their true purpose in some future state.

Let me endeavour to illustrate some of them.

I have here models of the changes that the chick undergoes in its development; and what they show might suffice for teaching the development of higher creatures. Now, nearly all we see here is the working out of a design, which cannot have its full end till some future time. These wings and legs—of what avail are they to the prisoner in the shell? Their purpose is not yet fulfilled; they are for the future. But if these be too plain to be impressive, let us look at more particular things.

Observe the changes through which the heart passes, from its first appearance as a little pulsating bag, to its being nearly fit for the time when the hatched bird will breathe in the open air. The changes are not merely a growth from a little heart to a big one; but are a series of acquirements of more complex shapes; so that the heart, which at first is a simple bag, then

becomes very curved, and then divides into two, and then into three and four, cavities. Now, doubtless, in each of these conditions, the heart is exactly appropriate to the contemporary state of the other organs, and the circumstances of the time of life; but each of them is, besides, a necessary stage of transition towards that more perfect state, that fitness for more complex duties, which the heart attains when the bird is born to breathe with lungs in the open air.

But I would descend yet lower, and, magnifying the wonders of these plans for the future, by diminishing (as it may seem to some) the importance of the objects in which they are displayed, would trace the development of a single blood-cell in a tadpole—i.e. in the young fish-like embryo of a frog, such as nearly every pool would supply in the spring-time, and such as magnified sketches would fully illustrate.

By a blood-cell I mean one of those microscopic particles by which the blood is coloured red: particles so minute that, in our own blood, about ten millions might lie on a square inch of surface.

In the earliest period of active life of these tadpoles, the little black and fish-like body is composed almost wholly of minute cells, among which you can trace, with even powerful microscopes, scarce any difference. You could not tell the future destiny of any of them by their present characters; they look all alike. But presently, as they increase in number, a differencing begins among them, and a sorting of them; and some arrange themselves for a spinal column, and some for muscles; and some are seen to be placed where the first streams of blood are to run; and some are clustered where the heart will be. At first, those that are to be blood-cells are round, and darkly shaded, and contain yellowish particles, many of which are like four-sided crystals of some fatty substance. But, in a day or two, the cells begin to move and circulate in the channels in which they were arranged; and then, as we watch them day by day, they gradually change. The particles within them become smaller and less numerous, and collect near to their borders; while their centres, clearing up, show an enclosed smaller body or nucleus. Moreover, as these changes proceed, the cells which were before colourless acquire gradually a deeper and deeper blood-tint, and exchange their round for an

oval shape; till, by the time that all the particles they first contained are cleared away, as if by solution, they have become perfect blood-cells, nearly like those which colour the blood of the completely developed frog.

The time required for these changes depends much on the temperature and degree of light to which the creature is exposed. It may vary from one to three or more weeks; and we can thus deliberately watch the development of a blood-cell, day by day, until it reaches that which we may call its perfection. In this state the cells abide for a time, unchanging; and then decline and give place to another set of blood-cells, each of which is developed through a series of changes different, indeed, from those that I have described, but not less numerous or complex.

Now, such is the life, up to the period of perfection, of every blood-cell in this trivial creature. And so it is in ourselves. Of the millions of those cells that colour our blood, not one reaches its perfection but through changes as numerous and great as these.

Perhaps the wonder is augmented if we think that, in the embryo, the changes proceed, with equal steps, in all the cells at once: there is exact concert among them; if I may so speak, they all keep time. Nor is the harmony limited to them: for their development is exactly adjusted to that of every other part; successive changes are exactly concurrent in every part at once; so that, though all are continually changing, they never lose their mutual fitness.

I might cite more instances of these plans for futurity; but they are nearly infinite; for in truth (and what a moral there is in such a truth!) in the living world, nothing is made at once fit for the highest purposes of which it may be capable. In all the countless crowds of living beings—in all the countless particles of each—there is not one but in the history of its life we may read a gradual attainment of its highest destiny: not one but has a time in which its true purpose is yet future, its true design yet unfulfilled; and, although, even in its rudiment, it is not useless, yet there will be a time when, with higher powers, it will take part in the designs of some more perfect state. So wide is that law, which has its highest instance in the history and future destiny of man himself.

But the evidence of the design of living bodies for conditions that are yet future, seems to culminate in the proofs of their capacity to repair injuries, and to recover from diseases.

It is surely only because it is so familiar that we think lightly, if at all, of the fact that living bodies are capable of repairing most of the injuries they may sustain; and that, in this capacity, they show that provision has been made in them, for events of which it is not certain whether they will ever occur to them or not. When we contemplate the perfect living body—the exact fitness of every part for its office, not as an independent agent, but as one whose work must be done in due proportion with that of many others, is a very marvellous thing; but it seems much more marvellous that, in the embryo, each of these parts was made fit for offices and relations that were then future; but surely more marvellous than all it is that each of these, when perfect, should still have capacity for right action in events that are not only future, but unlikely; that are indeed possible, but are in only so low a degree probable, that if ever they happen they will be called accidents—as things not to be expected or provided for.

Let me describe a process of repair, and describe it so simply, as it might be to schoolboys.

All know, or can feel, their Achilles-tendons behind their ankles, and that these, strong as they are, are sometimes broken by a violent contraction of their muscles. I know not how small—how almost infinitely small—the chance is that any given man, or quadruped, would ever break this or any other part; but small as the chance may be, ample provision is made for its repair. How this is accomplished may be again illustrated by diagrams.

When the tendon in such an animal as a rabbit is divided, its pieces separate to nearly an inch apart, the upper piece being drawn up by the unrestricted action of its muscles. The muscles, no longer fastened by the tendon to the heel-bone, are thus rendered useless; and the object of the reparative process must be to form a bond of connexion between the separated pieces of the tendon.

In the two days following such an injury, all the structures between and around the ends of the divided tendon appear soaked with a half-liquid substance, the product of inflamma-

tion. And thus far we see no plan for uniting the separated pieces; there is no more of this new substance in the line between them than there is around them; and all the new substance appears alike. But in the course of two days more, we find that fresh material is deposited between the separated pieces of the tendons, and that it is firmer than that around, and has firm hold on the ends of the separated pieces, and connects them, though as yet (if I may so say) only clumsily. After this, however, each day finds the connecting substance becoming firmer, tougher, and more like the texture of the tendon itself. Each day, too, it becomes more defined from the surrounding parts; and this it does, not only because itself becomes more exactly shaped, but because they regain their natural texture. And observe the distinct design which is shown in this contrast. At first, all the parts at and about the seat of injury were soaked with a similar material; but now, that portion of this material, which lay in the place for the formation of the connecting bond, has remained and contributed to the repair; but that portion of it which was more remote, and could serve no useful purpose, has been cleared away.

At the end of a week, in the rabbit, a complete cord-like bond of union is formed, and the muscles can act again. By this time, too, the bond has gained nearly the perfect texture and the toughness of the original tendon. I once tried the strength of such a bond of connexion, which had been forming for ten days after the division of the Achilles-tendon of a young rabbit. Having removed it from the dead body, I suspended weights upon it, and, after bearing weights of twenty, thirty, forty, and fifty pounds, it was at length broken by a weight of fifty-six pounds. But surely the strength it showed was very wonderful, if we remember that it was not more than the sixth of an inch in its greatest thickness, and that it was wholly formed in ten days, in the leg of a rabbit scarcely more than a pound in weight.

I might illustrate the process of repair by instances as perfect as these, observed after injuries of many, almost of any, parts. And I might, as in the instance of development, magnify its excellence by showing it in what we are apt to call trivial creatures, or even by showing that, in general, those lower species of animals. that have least means of escape or defence

from mutilation, appear to be endowed with the most ample powers of repair. But time will not permit this, nor yet that I should show how many lessons of practical utility might be engrafted on the teaching of a process such as this, or how the main principles of the surgery of injuries are based on the recognition of the natural power of recovery. Nearly its whole practice consists in the prevention of any interference with that to which there is, in the very nature of the body, as great a tendency as there is for the embryo to be developed into the perfect creature. Using the facts of the reparative process only for the present purpose of showing how physiology might be taught as the chief science of designs, I would say that the arguments of design, which are here displayed, are such as cannot be impugned by the suspicion that the events among which each living thing is cast have determined its adaptation to them; because the adaptations here noted prove capacities for things that are future, and only not impossible.

I will mention but one more instance of general design, which I think should not be omitted in the teaching of physiology to whatever class of students: that, namely, of the adaptation of animals in their decay; how, as they do not live, so neither do they decay nor die, for themselves alone, but ministering to others' good.

The chief evidence of this is in the provision that the decaying parts of animals yield the materials from which the vegetable kingdom derives its chief supply of food. In the ordinary decomposition of the dead body, many of the products are the very materials from which, as they are mingled with the earth and atmosphere, each plant takes its food. But it is not alone through this decay in death that animals restore to the vegetable world the materials which they have, for their own food, derived from it. The same rule is fulfilled in the decay of life; i.e. in those changes which occur when the particles of the animal body, having served their purpose, or lived their full time in it, are then to be cast out as refuse. For in all these changes, which are a part of that constant mutation of particles through which the body remains, through all the time of vigorous life, the same, though continually changing—in all these, the material which is passing out, as refuse, gradually approximates, in its transition, to the inorganic state of matter.

It is so with the carbonic acid and other exhalations from the lungs and skin, and with all the class of substances excreted. And thus, every form of degeneration or decay, whether in life or after death, may be described as a series of changes, through which the elements of organic bodies, instead of being on a sudden and with violence dispersed, are gradually collected into those lower combinations in which they may best rejoin the inorganic world; they are such changes that every creature may be said to decay and die and cast out its refuse in the form which may best fit it to discharge its share in the economy of the world—either by supplying nutriment to other organisms, or by taking its right part in the adjustment of the balance held between the organic and inorganic masses.

I have thus endeavoured to fulfil my office, and to show how the general teaching of physiology might do good among its students. I think its advantages are such as might be apprehended by students of all classes in society. I suppose, too, that for all that part of it which can be applied in the maintenance of health the merit of utility would be admitted; and that, in general terms, it would be allowed that the study of designs and final causes should be mingled with other studies in any scheme of education by which it is proposed that the whole mind should be disciplined, and all modes of reasoning should be taught.

But still, the question may be asked, is it possible that knowledge such as this, of the methods of design, will rest, with any influence, in a mind that must be engrossed in urgent business, or in household cares; harassed, perhaps, in struggles against poverty, or dissipated in the luxuries of wealth? It may be very well (some will say) to teach these things to the young, but men and women have other works and other pleasures to pursue.

I know all this; and I have overshot my mark if I have urged any teaching of which the effects would interfere with devotion to the necessary works of later life. But I suppose that, if any one will watch his thoughts for a few days, or even a few hours, he will find that, however engrossing may be his cares or his pleasures, however earnest his attention to what seems his most urgent need, there are yet intermingling trains

of thought quite alien from these: trains into which the mind falls, it knows not how, but in which it will wander as if resolute to refresh itself. Now these must be provided for; and so it must be an object of all education to supply, in early life, those studies from which, in later years, may arise reflections that may mingle happily with the business thoughts of common days; that may suggest to the reason, or even to the imagination, some hidden meaning, some future purpose, some noble end, in the things about us. Reflections such as these, being interwoven with our common thoughts, may often bring to our life a tone of joy, which its general aspect would not wear; like brilliant threads shot through the texture of some sombre fabric, giving lustre to its darkness.

But besides this happy influence of the general impressions that might remain in the mind from the early teaching of physiology, I claim for it the hope that its principles might read to some minds lessons of the truest wisdom.

The student of Nature's purposes should surely be averse from leading a purposeless existence. Watching design in everything around him, he could not fail, one would think, to reflect often on the purpose of his own existence. And doing so, if his mind were imbued with the knowledge of the mutual fitness in which all the members of his body, and all the parts of the whole organic world, subsist and minister to each other's good, he could not conclude that he exists for his own sake alone, or that happiness would be found separate from the offices of mutual help and of universal good-will. One who is conversant with things that have a purpose in the future, higher than that which they have yet fulfilled, would never think that his own highest destiny is yet achieved. Though his place among men might be only like that of a single particle —like that of a single blood-cell of the body—yet would he strive to concur, and take his share, in all progressive good. Nor would he count that, with his life ended, his purpose would be attained; but by teaching, or by record, or by some other of those means through which, in the history of our race, things that in their rudiments seemed trivial have been developed into great results, he would strive to "achieve at least some useful work, the fruit whereof might abide." Conscious of an immortal nature, and of desires and capacities for knowledge, which

cannot be satisfied in this world, he would be sure that the great law of progress, from a lower to a higher state, would not be abrogated in the Divine government of that part of him which cannot perish, and is not yet perfect. In him, even the understanding would be assured that, "as we have borne the image of the earthy, we shall also bear the image of the heavenly"; for that is the true lesson of development.

And because it abounds in lessons such as these, I claim for physiology the pre-eminence among all sciences, for the clear and full analogies which it displays between truths natural and revealed: and I would teach it everywhere; looking to its help, by these analogies, to prove the concord between knowledge and belief, and to mediate in the ever-pending conflict of intellect and faith.

ON THE IMPORTANCE OF THE STUDY OF ECONOMIC SCIENCE AS A BRANCH OF EDUCATION FOR ALL CLASSES

A LECTURE DELIVERED AT THE ROYAL INSTITUTION OF GREAT BRITAIN

By W. B. HODGSON, LL.D.

"Ignorance does not simply deprive us of advantages; it leads us to work our own misery; it is not merely a vacuum, void of knowledge, but a *plenum* of positive errors, continually productive of unhappiness. This remark was never more apposite than in the case of Political Economy."—SAMUEL BAILEY'S *Discourses*, etc., p. 121. 1852.

"If a man begins to forget that he is a social being, a member of a body, and that the only truths which can avail him anything, the only truths which are worthy objects of his philosophical search, are those which are equally true for every man, which will equally avail every man, which he must proclaim, as far as he can, to every man, from the proudest sage to the meanest outcast, he enters, I believe, into a lie, and helps forward the dissolution of that society of which he is a member."—Rev. C. KINGSLEY'S *Alexandria and her Schools*, L. ii, p. 66. 1854.

"A man will never be just to others who is not just to himself, and the first requisite of that justice is that he should look every obligation, every engagement, every duty in the face. This applies as much to money as to more serious affairs, and as much to nations as to men."—*Times*, June 6, 1854.

IT was truly said in this room, some weeks ago, by one whose departure from London we must all regret—Professor Edward Forbes—that "*It is the nature of the human mind to desire and seek a law.*" The higher desires of man have not been left, any more than his lower, without their object and their fulfilment, and just as the bodily appetite desires food, while the earth yields stores of nourishment—as the imagination craves for beauty, and beauty is on every side, so, responding to man's desire for law, does all Nature bear the impress of law. Not to the ignorant or careless eye, however, does LAW anywhere

reveal itself. The discovery of its traces is the student's rich and ever fresh reward. To men in general, the outward sense reports only a number of detached phenomena; their relations become gradually apparent to him only whose mental vision is acute enough, and whose gaze is steady enough, to behold them. SCIENCE, therefore, consists not in the accumulation of heterogeneous facts—any more than the random up-piling of stones is architecture—but in the detection of the principles which correlate facts even the most dissimilar and anomalous, and of the order which binds the parts into a whole. SCIENCE is, in brief, the pursuit of LAW; and the history of science is the record of the steps by which man in this pursuit rises through classifications, of which the last is ever more comprehensive than its predecessors, from the complexity of countless individuals to the simplicity of the groups, and from the diversity of the many, at least towards the oneness of the universal.

The discoveries, however, which it needed a Newton or a Cuvier to make, may be rendered intelligible in their results, if not always in their processes, to ordinary understandings; and whether our knowledge be superficial or profound, the belief in the omnipresence of law, in at least the physical world, has long ago taken its place in the convictions of the least instructed man. Let any one, then, who can realize mentally the difference between the aspect which the starry heavens bear to the quite ignorant beholder, and that which those same heavens present to the man most slightly acquainted with the discoveries of astronomy, or between the appearances of the vegetable world before and after some acquaintance with Vegetable Physiology: but who has never thoughtfully considered the phenomena of industrial life—let such a one station himself, say, on London Bridge, at high tide, and in the busy hour of day; let him watch the ever-flowing streams of human beings, each bound on his several errand,—the seemingly endless succession of vehicles, with their freight, animate and inanimate; let him look down the river, and observe the number and variety of shipping, coming and departing from and to all parts of the world, remote or near; let him observe, as he strolls onwards, the shops, and warehouses, and wharves, and arsenals, and docks, with their overflowing stores, the almost interminable lines of

streets with houses of every size and kind, each tenanted by its respective occupants; the railway stations from which and to which go and come, hourly, thousands of human beings, and the produce of the industry of millions of human beings; the electric telegraph, transmitting from town to town—nay, from land to land—the outward symbols of thought, with almost the proverbial speed of the inward thought itself; let him consider that within the range of a few miles of ground that produces, *directly*, none of the necessaries of life,* are gathered together more than 2,000,000 of men, women, and children, at the rate, in some parts, of 186,000 to the square mile; let him ponder how it is that all these people are daily fed, and clothed, and lodged,—how it is that all these things have been produced and are maintained; let him further consider that this stupendous spectacle is but a sample of what is going on, with great varieties, in so many other regions of the world; that people separated by thousands of miles of land and sea, who never saw each other, who, it may be, scarcely know of each other's existence, are busily providing for each other's wants, and each procuring his own sustenance by ministering to others' necessities or desires;—and then let him, without at all losing sight of the too obvious evil mixed up with all this, seriously ask himself, is this vast field of contemplation the theatre also of LAW, which binds the several parts together; or is it a mere giddy and fortuitous dance of discordant and jostling atoms—in a word, a huge weltering chaos, waiting the fiat of some Monsieur Cabet or Babœuf to reduce it to order, and convert it into a cosmos, by persuading or compelling the several atoms to adopt some cunningly devised principle of so-called "organization of labour"? To this question Economic Science professes, at least, to supply the answer; and if *science* be the pursuit of law, and deserve the title in proportion to its success in that pursuit, the claims of Economic Science must be tested by the nature of the reply it gives.

* "Moyhanger, a New-Zealander, who was brought to England, was struck with especial wonder, in his visit to London, at the mystery, as it appeared to him, how such an immense population could be fed; as he saw neither cattle nor crops. Many of the Londoners, who would perhaps have laughed at the savage's admiration, would probably have been found never to have even thought of the mechanism which is here at work."—Archbishop WHATELY, *Introd. Lect. to Polit. Econ.*, L. iv, p. 97. Second Edition. 1832.

It may occur to some who hear me that the term LAW is not applicable in the same sense or way to the various classes of phenomena which I have casually indicated. In the first—the region of astronomy—LAW suggests the idea of some mighty force which irresistibly compels motions on the grandest scale; in the second—the vegetable world—it suggests rather a mere principle of arrangement, according to which certain unresisting bodies are distributed; while in the third—the Economic World of Man—a vast difference appears between it and the other two, inasmuch as we have here a multitude of independent intelligences and wills, acting consciously and voluntarily from within, in every variety of direction, and often in seeming opposition to each other. This difficulty merits a consideration, serious if brief. Between the first and second the difference is not real, but only apparent. The growth of a plant is as wonderful—as grand an exercise of power as the revolution of a planet; and gravitation, as we call it, no more than growth, is in itself a power; both are alike expressions and results of that WILL which is in the universe the only real power—the only true cause. Our very word *order* has a double sense—*arrangement* and *command:* so natural is it for us to identify the one with the other, and to believe that arrangement or system exists only by command or LAW. And, in truth, throughout all things, however diverse the special phenomena, whether it be the sweep of a comet, or the budding of a flower, we can recognize still only a principle or method of arrangement as the result of WILL; and it is because these are so closely and invariably connected in our minds that we are so apt to use the word LAW sometimes for the one, and sometimes for the other, personifying Law, just as we do Providence in ordinary speech.

The real difficulty, however, lies in the third case, that is, the subject immediately before us. Having seen the *prima facie* and analogical improbability of the notion that the economic world is *lawless*, the question arises—in what way does LAW operate amid so many seemingly independent and conflicting individualities? I have no desire, and there is happily no need, for long or subtle disquisition. I would merely submit a consideration in itself quite simple, but fraught, if I mistake not, with the most important practical results. In the purely

inorganic world, law operates irresistibly, and command and obedience are strictly coincident, co-extensive, and identical. In the motions of the heavenly bodies, for example, there is no *eccentricity* in the popular sense of the term; even the orbit of a comet, between whose successive reappearances many decades of years and whole generations of men pass away, is absolutely known—eclipses with the longest intervals are certainly foretold. The same fact holds in the organized but inanimate world, as in the world both inanimate and unorganized. As we ascend in the scale, and enter on the animate creation, we find a like fixity and uniformity provided for *to a very large extent* by that most marvellous faculty—*Instinct*, which guides almost infallibly the lower orders of animals, which maintains an almost precise sameness among the most distant generations, and conducts all surely and unconsciously to the end of their being. But MAN is a being vastly more complex in his nature; he, too, has instincts, but these form a much smaller proportion of his whole faculty; * with all that the lower orders of being have, he has much more besides—moral faculties, reason, and will, both the latter differing vastly in degree, if not in kind, from those of any other creature. The part which he has to play in creation is proportionally complex; and here it is that perplexity, and discord, and confusion begin to appear, or at least chiefly manifest themselves. It is this surface confusion which hides from us the central and pervading LAW, and makes it difficult to trace its operation. The laws or conditions, however, which determine human well-being are really as fixed and absolute as are the laws of planetary motion; but man, though so constituted as to desire and seek his well-being, has not an infallible perception of that in which it consists, or of the means by which this end is to be attained. We find throughout, this distinction between man and the lower animals. Thus other animals are gifted by nature with the clothing suitable to their condition, and it even varies in colour and thickness according to the seasons. Man alone has with effort to construct what clothing he requires; so, more or less,

* "It would seem that it is in the proportion which their instincts and intelligence bear to each other that the difference between the mind of man and that of other animals chiefly consists. Reasoning is not peculiar to the former, nor is instinct peculiar to the latter.—*Psychological Inquiries*, by B. C. B., p. 186. London. 1854.

is it with food; so is it with shelter. Is this an inferiority on the part of man? Surely not; for it is by this very discipline that his higher faculties are called into play, and enlarged, and strengthened. What appears a penalty is, in reality, a blessing. Nature's very provision for the comfort of bird or beast seems, at the same time, the sentence of incapacity for improvement. Man, however (I speak now of the individual), is progressive, being capable of improvement; and he is stimulated to improvement because his wants are not supplied for him, but he is compelled to supply them for himself, and his desires ever grow with the means of their gratification. The whole universe is thus, in truth, a great educational organization—a great school,—for the calling out and the direction of what powers are in man latent. But his progress is not a smooth advance from good to better; his way lies through evils of many kinds—evils attendant inseparably on defective knowledge and ill-regulated desires. LAW, which in the physical universe operates UNI-*formly*, here operates, so to speak, BI-*formly;* the law wears, Janus-like, two faces; but it is one law nevertheless. It assumes, however, a twofold sanction, reward for obedience, punishment for disobedience, each being but the complement and corollary of the other. Thus the pallid face and irritable nerves of the sedentary student, the ruddy cheek and iron muscles of the ploughman—the trembling hand and bloodshot eyes of the drunkard, the steady pulse and clear open countenance of the temperate man—are the results not of two antagonistic laws, but of one law, vindicating its majestic universality in the one case not less than in the other. So is it with the stagnant and pestilential swamp as contrasted with the cultivated plain; the ruined village with the thriving town; the land of inhabitants few but poor with the land of inhabitants many and rich. It is this difference, accordingly, which in the human sphere translates LAW into DUTY, and the MUST of the Physical World into the OUGHT of the Moral. Wordsworth, the most philosophical of poets, has not failed to detect their kinship, however, when, in his noble "Ode to Duty," he says:

Flowers laugh before thee on their beds,
And fragrance in thy footing treads:
Thou dost preserve the stars from wrong,
And the most ancient heavens through Thee are fresh and strong.

Good, then, being the great end of all the established conditions of our life, evil is, and must ever be, the result of their violation. As Paley has said that no nerve has ever been discovered whose function lies in the giving of pain, so, in all things, pain or evil follows the breach, not the observance, of a law. But this very pain or evil is not in its end vindictive, or simply punitive; its aim is reformation for the future, not merely punishment for the past. The child burns its finger in the candle flame, cuts its hand with a knife, makes a false step and falls, and profits all its life through by the lessons it has gained. And so the exhaustion of mind or body from over-exertion, the headache from intemperance, are Nature's solemn warnings, tending powerfully to prevent future transgression. Man's successes and his failures are both, in different ways, instructive; both help him in his career.

But Man is progressive not only as an individual, but as a race. Here, still more, is his superiority to all other animals apparent. He is, in some measure, the heir of the discoveries, the inventions, the thoughts, and the labours, of all foregoing time; and each man has, in some measure, for his helper, the results of the accumulated knowledge of the world. But the transmission of experience and knowledge from generation to generation is the fundamental condition of progress throughout the successive ages of the life of mankind. To a large extent, of course, we cannot but profit from the labour of our predecessors; all those products, and instruments, and agencies, which we style "civilization," our roads, our railways, our canals, our courts of law, our houses of legislature, and a thousand other embodiments of the combined and successive efforts of many generations, are our inheritance by birth; but the very guidance and employment of these for their improvement, or even for their maintenance, require ever increased knowledge and intelligence. The higher the civilization that a community has attained, the more, not the less, necessary is it that its members, as one race succeeds another, should be enlightened and informed. No inheritance of industrial progress can dispense with individual intelligence and judgment any more than the accumulation of books can save from the need of learning to read and write. But thousands of human beings, born ignorant, are left to repeat unguided the same

experiments, and to incur the same failures and penalties as their parents—as their ancestors. Where these stumbled, or slipped, and fell, they too stumble, or slip, and fall, rising again perhaps, but not uninjured by the fall. Nature teaches, it is true, by penalty as well as by reward; but it is surely wise, as far as may be, to anticipate in each case this rough teaching, to aid it by rational explanation, and to confine it within safe bounds. The world, doubtless, advances in spite of all.* That industrial progress is what it is proves that the amount of observance of law is, on the whole, largely in excess of its violation; were it otherwise, society would retrograde, and humanity would perish. This predominance of good results from the very constitution of human nature and of the world, by which the individual, working even unconsciously and for his own ends, and learning even by failure, achieves a good wider than that he contemplates, and by which progress, in spite of delay and fluctuation, is maintained alike in the individual and the race. But how shall the evil which yet mars and deforms our civilization be abated, if not removed, while progress is made more rapid, and sure, and equable? Both depend alike on increased observance of law; and it is by diffusing knowledge of its existence and operation that observance of law is rendered more general and less precarious. If, then, we would convert not only disobedience into obedience, but obedience blind, unconscious, and precarious, into obedience conscious, intelligent, and habitual, we must teach all to understand the nature of the laws on which the universal well-being depends, and train all in those habits which facilitate and secure the observance of those laws.†

Assuming, then, that in the industrial or economic sphere the laws of human well-being are as fixed as in any other, and that what measure of well-being we anywhere behold is the result of obedience, conscious or unconscious, to those laws, we ought next to inquire what those LAWS are. As a preliminary, let us take a hasty survey of the steps by which any people ascends from barbarism to civilization, from destitution to

* "There is this difference between the body politic and the physical frame. Life is 'a harp of thousand strings, that dies if one be gone'; but the life of society is still living and tuneful, though many strings be broken."—*Times*, June 8, 1854.

† *Vide* Appendix, p. 200.

comfort, from poverty to wealth. From the review alike of good and of evil, we shall be able to extract the principles which run throughout, and which both good and evil concur to attest. In barbarous countries we find men scattered in small numbers over wide extent of territory, living by hunting or fishing, or both combined; every man supplies his own wants directly; he makes his own bow and arrows; he kills a buffalo for himself; with hides stripped and dressed by himself, he constructs his own robe or tent; he lives from hand to mouth, feasting voraciously to-day, then starving till another supply of food can be obtained; ever on the verge of famine, and eking out a precarious subsistence by robbery and murder, which he calls war. All but the strong perish in early years, and the average duration of life is low. If we contemplate the pastoral life instead of that of hunting and fishing, still we find that large tracts of country are needed for the maintenance of few people. If the earth be at all cultivated, it is with the rudest implements, and the produce is proportionally scanty. So long as each man is entirely occupied in providing for his own wants, progress is impossible. So soon, however, as by the gradual and slow introduction of better implements, and the acquirement of greater skill, agriculture becomes more productive, and the labour of one man becomes sufficient for the support of more than one, of some, of many; the first condition of progress is realized, and the labour of some or many is now set free for other occupations. Food and clothing, fuel and shelter, are the first necessaries of life. But instead of every man preparing all these for himself directly, instead of every man making for himself all that he requires, gradually one man begins to construct one article, or set of articles only, while another devotes himself to another, with a consequent great increase of productiveness in each case, from increased skill and economy of time; in other words, the *division of labour* is begun. But so soon as the industry of the community is thus divided, and that of each thus restricted, as each still requires all the articles which before he constructed for himself, he can obtain them only from those who employ themselves in their production; and this he can do only by giving some of his own product as an equivalent, in other words, by *exchange*. This transaction gives meaning to the term *value*, which

denotes simply the amount of commodities that can be procured in exchange for any other commodity. Division of labour and exchange are thus simultaneous in their origin. From the introduction of exchange, industrial progress gains a fresh life. Industry having been thus rendered more productive than before, subsistence is now provided for a larger number of persons than before. The reward of industry increasing with its productiveness, ingenuity is stimulated to the invention of improved methods, and of improved instruments called *tools*, or, as they become more complicated and powerful, *machines*, though a machine is in principle only a tool; and the very argument which is good, if good at all, against a steam-plough is good against the common plough, or a hoe, or a spade, or a stake hardened in the fire.

Population having meantime increased, the land available for production becomes more and more fully appropriated; and as one portion is more fertile, or more advantageously situated than another, it becomes more advantageous to pay a portion of the produce for the right to cultivate a more productive soil, than to cultivate an inferior soil even for nothing; e.g. to pay ten measures of grain for a soil which produces fifty measures, than nothing for a soil which produces, say, thirty or thirty-five; and hence arises what we call *rent*. But, meantime also, the productiveness of industry having become ever greater in proportion to the consumption of its produce, the process of accumulation goes on, and the unconsumed results of previous labour, which, however various their kinds, we term WEALTH, swell to larger proportions. But this wealth is not equally possessed by all; one man, from superior skill, or intelligence, or economy, or other causes, coming to possess more than others, while some, it may be, possess none at all. Mere labour, however, without the results of foregone labour, embodied in some form, can accomplish little; while the results of foregone labour, in whatever form embodied, need fresh labour in order to become still more productive. Thus, e.g. a spade is a result of past labour; without it the labourer could accomplish little; and, on the other hand, the spade, without a labourer to wield it, would be unproductive. Now, the spade here represents that portion of wealth which is devoted to further production, and which is called CAPITAL. Capital and labour are thus

indispensable to each other. They may exist in different hands, or in the same; but they must co-exist, and co-operate. Thus —if we suppose them to be in different hands—the owner of the spade, whom we may call the *capitalist*, may undertake to give the *labourer* a fixed compensation for his labour aided by the spade (an amount which will more or less exceed, and can in no case fall below, what the labourer without the spade can earn), reserving for himself any surplus that may arise after that labour is paid. In this case the labourer's reward is called WAGES; the capitalist's reward is called PROFIT. Or the *capitalist* may lend the spade to the *labourer* for a fixed return (which will be somewhat less than, and which cannot exceed, the difference in the labourer's productiveness, caused by the spade), the labourer claiming as his own all that he can realize over and above what he pays. In this case the labourer's return, whatever it may be called, is partly wages and partly profit, while the capitalist's return is termed *interest*, or much better, *usance*, an obsolete English word, for it is really what is paid for the *use* of capital in any form. If the capital and labour be in the same hands, e.g. if the labourer own the spade he uses, the joint return ever consists of the two items here discriminated.

As industry extends and wealth increases, it is early found necessary to provide for the security of property; for the suppression of violence and fraud; and for the settlement of disputes that will here and there arise, even without evil intention on either side. Hence all the machinery of courts of justice, and of government, from its highest to its lowest functionary. As these, though not in themselves directly producers, are indispensable to production, and exist for the welfare of all, they must be maintained at the expense of all; hence comes TAXATION of various kinds, which it is the business of the legislature to impose justly, and in the way least likely to fetter industry, and prevent increase of wealth.

So far as we have hitherto seen, exchanges have as yet been effected by direct giving and taking of commodity for commodity, or, as it is termed, *barter*; but great and serious difficulties attend this system, difficulties ever more deeply felt as exchanges multiply and become more various; the baker may not want the shoemaker's shoes, if the latter want hi

bread; but the latter may not want as much bread as equals the value of a pair of shoes; and payment by a half or a third of a pair of shoes is impossible. A medium of exchange, accordingly, is introduced; usually the *precious* metals, as they are called, the very word implying one of their fitnesses for the task—viz. that in a small bulk they contain great value. The non-liability to decay; capability of division without loss; comparative exemption from fluctuations of supply; and facility of recognition, are among their other claims. Exchange, thus facilitated by the adoption of a medium which all are ready to receive, and by which most minute proportions of value may be easily represented, proceeds with vastly increased rapidity; and value being thus measured habitually in money, we have the new element of PRICE. Though money in itself is but a very small portion of the capital, and still less of the total wealth, of a nation, it so habitually represents every kind of capital and wealth that it conveniently becomes a synonym for both, not, however, without some risk of mental confusion and error as the result.

Exchanges becoming thus continually more frequent and complicated, it is found convenient and advantageous, on the principle of the division of labour, that a class of men should devote themselves to conduct the business of exchange solely, the work of production being left to others. By the introduction of *merchants*, who do not themselves produce, a greater amount of production is attained, on the whole, than would be possible if all both produced and exchanged without their intervention.

But, for facility and frequency of exchange, even at home, rapidity, and ease, and safety of communication are indispensable; good roads, swift conveyances, canals, and ultimately railways arise, with their adjuncts of carriers and couriers, and post-establishments, and telegraphs of ever greater ingenuity and efficiency.

Exchange, which was at first confined within the limits of one country, soon extends to other countries, with an immense advantage to all, for all are thus made partakers in the productions of each, which are more and more diverse according to their diversity of climate. Foreign commerce, with all that it involves of ships, and docks, and warehouses, is the most

powerful stimulus to home industry. But exchange, whether at home or abroad, is, in all cases, when analysed, simply each man's giving something that he wants less, for something else that he wants more.

As geographical knowledge and means of transit are increased, numbers pass from one country to another; from countries densely to those less densely peopled; from countries where land is all appropriated to those where it is still unclaimed; from countries where capital and labour are comparatively unproductive to those where both are more amply rewarded; new fields being thus perpetually opened up for human industry, and increased enjoyment provided by fresh and ever augmented interchange, both for those who go and for those who stay.

But long ere this, as yet the highest, stage of progress has been reached, the precious metals themselves have been found incompetent to discharge the full duty of exchange; and paper money, or duly vouched promises to pay money, is introduced with an ever more complicated machinery of bank-notes and bills of exchange, for the management of which class of transactions a still further division of labour is introduced by means of bankers, bill-brokers, and the other agents by whom what we call comprehensively CREDIT is carried on.

But life and property are subject to contingencies which involve serious loss, and which it is impossible always to prevent. It is discovered that the evil results to individuals, which would be ruinous to one, may, by combination, be distributed over many. Hence insurances against fire, against death, against disaster at sea, against hail-storms and diseases among cattle, against railway accidents, and even against fraud on the part of clerks or other assistants, all of which are based on calculation of averages, this again being based on the conviction that a certain regularity prevails among events even the most anomalous and irregular.

And thus, step by step, by a strictly natural course, does the work of industrial progress go on, till we witness its gigantic results in our own time and our own land—results of which the great Crystal Palace (the opening of which was not inaptly coincident with the day fixed for this exposition of the principles whose triumph it exemplifies) may be justly regarded as the crowning and most various illustration—raised, as it has been,

by voluntary combination, on strictly economic grounds, and embracing within itself, in one vast space, examples of the productions of the labour, the ingenuity, the fancy, the skill, the science of all ages and of every land.

In this inevitably brief and incomplete sketch of the industrial progress of the world, not only has much been omitted, but it is to be observed that the steps do not always follow each other in precisely the same order, and that much that is here recorded, perforce, successively, takes place simultaneously. It is not possible here or now to extract from even this most hasty sketch the merely *theoretic* principles which it involves. This is the business of a long course of lectures, and it is not, besides, my purpose to expound Economic Science itself, any further than may be indispensable to show its importance as a branch of general instruction. Let us rather look at some of the great *practical* lessons that may be deduced from it for the guidance of individual conduct.

Everything, then, that we or others possess, is more or less the result of human, that is, of individual, industry. It is observable that not where nature itself is most prolific is human labour the most productive; so true is it that necessity is the mother of invention and of industry as well. Truly has Rousseau remarked, "In the south, men consume little" (he might have said *produce* little) "on a grateful soil; in the north, men consume much" (and of course *produce* much) "on a soil ungrateful." * Where man has most done for him, he often does least for himself; and though his labours must be seconded by the productiveness of Nature, the latter is really more dependent on the former than the former on the latter. Now this law holds true of the future as well as of the present or the past. Every human being must subsist on the produce of his own industry, or on that of some one else. *Industry*, then, is the first duty of him who would be honourably independent.

But it is not by present labour, any more than by future, that any man is really sustained. While the crop is growing, for example, the labourer is fed by the grain of former harvests. Now, if the produce of labour were consumed as fast as it is produced, not only would progress be impossible, but life itself

* *Emile*, Liv. I.

would be endangered, and would ere long cease. Hence the duty of what is called, in its narrower sense, *economy*, or the frugal and prudent consumption of what has been produced. Disasters, too, will arise, which no human wisdom can prevent, but against whose consequences it may provide. The very progress of industry involves *displacement* of labour, though it is not true that labour is so *superseded*, as the phrase is. The invention of printing threw *amanuenses* out of their old employment, though it soon employed a thousand men instead of one. During all such transitions, it is only by previous savings that those thus affected can be maintained till they can adapt themselves to the change. Again, the early years of every human being are incapable of industrial effort, and the child must be maintained by the previous labour of others. Upon whom this duty fairly falls, whether on some abstraction that we call the State, or society, or on the parents of the child to whom his being is due, is a question which needs less to be asked than merely to be suggested here. Again, the years of labour are limited; the evening of that night approaches in which no man can work, and here is another call on the proceeds of past industry. The very old, as well as the very young, must be supported alike by foregone labour; in the case of the young, it must be by the labour of others; in the case of the old, it must be either by their own previous labour, or by that of their children now grown up, or by that of society at large—which way is best is surely not doubtful. During the years of active life itself, sickness will sometimes invade, throwing men often for long periods on the resources of the past. Hence the necessity of *forethought* as regards equally the future of others whom affection and duty alike commend to our care and our own, when the days of decay and weakness shall arrive. Now, *forethought* involves *judgment*, and *diligence*, and *self-denial*. (1) As to judgment. Earnings may be saved, but if injudiciously invested, they may be lost. To take a simple case—hoarded potatoes are a more precarious economy than hoarded grain; and so throughout where savings are invested through banks, or building societies, or railway shares, or in any other way. The division of labour itself calls for ever fresh exercise of judgment. So long as each man produces all that he wants for himself, he knows precisely what he wants, and how much;

but so soon as labour is divided, each man produces not what he wants himself, but what others want, or are supposed to want. If, then, any one produce by mistake articles which others do not want, or of a quality or to an extent at variance with the demand, he suffers serious loss, it may be ruin. (2) As to diligence. Without this, labour is little different from idleness. But mere labour, however diligent, can accomplish little unless guided by *intelligence*, for which, as the demands of society increase, there is an ever louder call. *Knowledge*, then, is indispensable to the attainment of any beyond the lowest results of industry. The more we know of the nature of that on which, and by which, and in which, and for which, we work, the more likely, nay certain, is our work to turn to good account. This knowledge, when embodied in practice and confirmed by it, becomes *skill*. The very tools and machines which some fancy supersede human labour and skill are the results of both, and they render the former infinitely more productive, and call for ever more of the latter for their improvement, if not for their actual guidance. (3) As regards self-denial. One of its most important forms is *temperance*, without which labour, especially of the higher kinds, is precarious, it may be impossible. As society advances, the relations of man to his fellows become more and more numerous and complex. *Credit*, as it is well called, holds a larger and larger place, and reliance on each other's faith becomes more and more important. *Honesty*, accordingly, whether in its lower forms, such as *punctuality*, or in its higher, to which we give the name *integrity*, is thus an indispensable condition of human progress. Were the exceptions to this condition to become much more frequent, the bonds of human society would be proportionally loosened, and civilization would go backward. In scarcely a subordinate degree are civility, courtesy, mutual forbearance, and willingness to oblige, necessary to oil the wheels of the social machine, which, without these, would move but slowly and creakingly along. These things we all need in our own case; and to be received they must be given.

It is only in so far as all these qualities of diligence, and economy, and skill, and forethought, and intelligence, and temperance, and integrity, and courtesy, have been manifested that wealth has been created, and that society in any age or

country has advanced. It is just in so far as these have been neglected that poverty, and misery, and evil, of every kind, abound. Such are some of the chief practical lessons of Economic Science when rightly studied.

And will any one ask, "Are these mere truisms the boasted results of economic teaching?" In reply, much may be said. What is a truism to one mind, say to all here, may be *really* unknown to thousands beyond these walls. In such subjects, again, the profoundest truth is ever the simplest. It is its very simplicity that blinds us to its value and comprehensiveness. Further, we are so easily familiarized with the mere names of duties, and so accustomed to assent with the lips to their obligation, that we neglect to consider either their basis or their practical working. We go on daily assenting to truths we daily violate; it is not uncommon to lecture on ventilation in rooms whose atmosphere is stifling; to eulogize economy in the midst of reckless expenditure; and health is sometimes injured by very diligence in the study of its laws. What men all want is not merely the discovery and promulgation of new truth, however useful, but the freshening up of old truths long ago admitted. The coins which we carry about with us, and which pass continually from hand to hand, have had the sharpness of their edges worn off, their legend all but effaced. We need to have them cast anew into the mint of thought, and re-stamped with their original "image and superscription." Rote-teaching is pernicious in morals not less than in merely intellectual matters. The explanation of a law, its demonstration, should ever go hand in hand with its inculcation. For the sake of those who may say, or at least think, "All this we knew long ago," let me use an illustration from the quite parallel case of *Physiology*. In my younger days I was accustomed to hear much vague talk about air and exercise; on all hands I heard that nothing was so good as exercise and fresh air. Well, so long as the restless activity of boyhood lasted, there was less need for instruction on this head; boys take fresh air and exercise in blind obedience to a blessed law of their nature. But when youth came on, and intellect became more mature, and books began to push cricket from its throne, all the rumour about air and exercise was quite inoperative to prevent long days and late nights of sedentary position, of confinement in

close room , of hard work of the brain, while the circulation of the blood was impeded, the lungs laboured, the muscles lost their energy, and the skin its freedom of transpiration and its vigour to resist agencies from without. When, like most of you, I listened in delight to the beautiful expositions of my immediate predecessor, perhaps I was not alone in thinking that, had we all been taught in early life the economy of the lungs, and heart, and blood-vessels, and brain—had we been shown that the blood which nourishes the body must be purified by frequent contact with the outer air; that for this purpose it passes frequently through the lungs, receiving from the air fresh life, while its impurities are thrown off; that in the process of breathing the air is rapidly deteriorated and rendered unfit to sustain life, constant renovation being thus required; that by muscular compression consequent on exercise the circulation is quickened, as well as the breathing, so that the blood is thus more rapidly purified, the effete particles of matter are more quickly removed, and our bodies in truth more frequently and healthfully renewed—we should many of us have been spared much suffering and much loss of power arising necessarily from violation of the vital laws. And so with Economic Science. It is of no avail to repeat by rote phrases about industry, and temperance, and frugality, etc. The results of the observance and of the violation of those duties, as exemplified in the actual working of social life, must be clearly shown, and so enforced that the knowledge shall be wrought into the very tissue and substance of the mind, never to perish while life lasts, so that all things shall be brought to the test of the principles thus incorporated with the intellect itself. Further, in the case of both sciences alike, mere teaching, or addressing of the intellect, even if that be convinced, is not all, or enough. *Training* must accompany *teaching;* the formation of habits must go on with the clearing of the intellectual vision. I speak not of schools alone, or of homes alone; in both must the embryo man be accustomed, as well as told, to do what is right. He who has once learned by habit the delight and the advantage of daily ablution of the whole body, or of daily exercise in all weathers, in the open air, will not easily abandon or interrupt either of these habits. And so with industry and the rest. Every fresh act of obedience is no longer, as it were, the effort of a distinct

volition, but an almost automatic repetition of an act first commanded by reason. This conversion of the *voluntary* into the *spontaneous* is the true guarantee for perseverance in any line of conduct, the excellence of which has been already recognized by the understanding.

The analogy between the Physiological and the Economic Sciences, both in their nature and in their present position, seems to me to hold throughout. Thus ignorance does not in either confer any exemption from the evils attending the breach of any law, however it may be admitted in extenuation at the bar of human justice. The child who takes arsenic for sugar, dies as surely as the wilful suicide. The youth launched on this busy world without any of the knowledge here indicated, finds Greek iambics, and even conic sections, of no guidance in its industrial relations, and he suffers and fails accordingly. What is the inference? That ignorance should be removed, and evil prevented, by early teaching, rather than left to the bitter regimen of experience. Coleridge has finely compared experience to the *stern* lights of a vessel, which illuminate only the track over which it has passed. It is for us rather to fix the light of knowledge on the *prow*, to illumine the course which the ship has yet to take. It would surely be a great gain were all offences against economic law reduced to the category of wilful disobedience, in spite of knowledge; for such, I firmly believe, are, especially at the outset, vastly the minority.

Again: Health, much as it depends on individual observance of its laws, is greatly dependent on their observance by others also. The profligate parent transmits a feeble and sickly organization to his child; just as opposite conduct tends to the opposite result. The pestilence which foulness in one part of a city has bred, extends to other parts; and the consequences of the offence spread far beyond the original offender. So, economically, does each man suffer for others' transgressions besides his own. The idleness, and wastefulness, and intemperance of parents entail hunger, and raggedness, and every form of misery on the unhappy children. The industrious, and provident, and honest members of the community are stinted in their means for the support of the idle, and improvident, and dishonest, and for their own protection against the depredations of those who seek to live by others' labour rather

than their own. No law of our existence is more sure than this. It is idle to cavil or complain. Let us rather see how the recognition of this law should affect us. What is the practical inference? It is that the interests of humanity are one; that throughout mankind there is, in French phrase, a *solidarity*, which renders each responsible, in some measure, for the rest. The policy of selfish isolation is, therefore, vain, as well as sinful. We suffer from our neglect of the well-being of our fellow-men. The gaol fever, which the gross negligence of prison authorities produced in former days, slew the juryman in the box, and even the judge upon the bench. And it is not in purse alone, or even chiefly, that we suffer from the existence of the destitute or the depraved. The great mountain of human evil throws its dark, cold shadow on every one of us; in such an atmosphere our own moral nature droops and pines; and just proportioned to the mental elasticity which attends every successful effort to spread good around us is the numbing and hardening pressure of that great mass of vice and misery which we feel ourselves impotent to relieve.

One more analogy I would briefly note. We know how common quack medicines are. Why is this? Because, through ignorance of physiological laws, people are silly enough to believe that any nostrum can exist potent to repair, as by a magic spell or incantation, the evil results of their own neglect of health and its conditions. To such people, talk about air and exercise, and washing, and regular diet, and early hours, and temperance, and alternation of labour and rest, is very uninteresting and commonplace. To a similar class of persons discourse on diligence and economy, and forethought and integrity, is very dull. "What is the use of all your chemistry," said the old lady, "if you cannot take the stain out of my silk gown?" And by tests not less narrow and erroneous are the teachings of science, whether economical or physiological, often tried. But a change is coming over the public estimate of the latter, at least in this respect. *Prevention* is being ever more thought of than *cure;* or, in technical phrase, the *prophylactic* claims, and now receives, more attention than the *therapeutic* portion of the physician's art. Pure water, and fresh air and light are now, almost for the first time, really recognized as the fundamental and indispensable conditions of health; and baths,

and drains, and ventilators, and wash-houses, are fast encroaching on the domain of the blister and the lancet, the pill and the black draught. Now, what systems of the treatment of disease are to Sanitary Physiology, Poor-laws and Charitable Institutions and Criminal Legislation are to Economic Science. It aims at preventing the evils which those seek to deal with as they arise. The attempt may never quite succeed; but its success will be exactly proportioned to the vigour and unanimity with which it is made. It seeks to treat the source of the disease, rather than the mere symptoms. It is only as the former is removed that the latter will disappear. By all means let no palliative be neglected in the meantime, but let no cure be expected therefrom. Efforts to *perfect* systems of poor-laws, or criminal laws, however excellent or useful, must be abortive, because the very existence of the evils which these address is abnormal; and it is for the removal of these wens and blotches on the social system that we must strive, not for their mere abatement by typical applications, or the rendering of them symmetrical and trim. Wisdom and Benevolence here meet, and are at one.*

Yet persons are not wanting who meet our desire that Economic Science should be taught to all, and especially to the young, by the cry that "it tends to make men selfish." In reply, I will not content myself with saying, in the words of Shakespeare, "Self-love is not so vile a sin as self-neglecting." I go much further, and assert that this teaching, if properly conducted, has precisely the opposite tendency. Its great purpose is to show how the community is enriched by the industry of the individual, and how the value of individual industry is measured by its result in enriching the community. It wholly disowns and condemns every mode of enriching the individual at the general expense, or even without the general advantage. Thus, the merchant who brings a commodity, say tea, from a country where it is cheap to one where it is dear, and gains a profit by the transaction, fulfils the conditions of Economic Science. He serves at once the community in which he lives by bringing an article from a place where it is less, to a place where it is more, wanted; and the community with

* In the text I have merely pointed out *analogy*. Here let me hint at *dependence*. Is not the economic difficulty the main obstacle to sanitary arrangements?

which he trades by giving them in exchange for the article they sell something that they value more. But the man who enriches himself at the gaming-table, or by other means more or less resembling the picking of pockets, does injury, not service, to the community. He is wholly out of the pale of Economic Science; he may be a *chevalier d'industrie*, in the French sense, but Economic Science disowns his industry, and condemns him as a wasteful consumer of what others have produced. It teaches every man to look on himself as a portion of society, and widens, not narrows, his views of his own calling.

And here I cannot but express my deep regret that one to whom we all owe, and to whom we all pay, so much gratitude, and affection, and admiration, for all he has written and done in the cause of good—I mean Mr. Charles Dickens—should have lent his great genius and name to the discrediting of the subject whose claims I now advocate. Much as I am grieved, however, I am not much surprised, for men of purely literary culture, with keen and kindly sympathies which range them on what seems the side of the poor and weak against the rich and strong, and, on the other hand, with refined tastes, which are shocked by the insolence of success and the ostentation incident to newly acquired wealth, are ever most apt to fall into the mistaken estimate of this subject which marks most that has yet appeared of his new tale, *Hard Times*. Of wilful misrepresentation we know him to be incapable; not the less is the misrepresentation to be deplored. We have heard of a young lady, who compromised between her desire to have a portrait of her lover, and her fear lest her parents should discover her attachment, by having the portrait painted very unlike. What love did in the case of this young lady, aversion has done in the case of Mr. Dickens, who has made the portrait so unlike that the best friends of the original cannot detect the resemblance. His descriptions are just as like to real Economic Science as "statistics" are to "stutterings," two words which he makes one of his characters not very naturally confound. He who misrepresents what he ridicules, does, in truth, not ridicule what he misrepresents. Of the lad Bitzer, he says, in No. 218 of *Household Words*:

> Having satisfied himself, on his father's death, that his mother had a right of settlement in Coketown, this excellent young economist had asserted that

right for her with such a steadfast adherence to the principle of the case, that she had been shut up in the workhouse ever since. It must be admitted that he allowed her half a pound of tea a year, which was weak in him: first, because all gifts have an inevitable tendency to pauperize the recipient; and, secondly, because his only reasonable transaction in that commodity would have been to buy it for as little as he could possibly give, and to sell it for as much as he could possibly get; it having been clearly ascertained by philosophers that in this is comprised the whole duty of man—not a part of man's duty, but the whole. —(p. 335.)

Here Economic Science, which so strongly enforces *parental* duty, is given out as discouraging its moral if not economic correlative—*filial* duty. But where do economists represent this maxim as the whole duty of man? Their business is to treat of man in his industrial capacity and relations; they do not presume to deal with his other capacities and relations, except by showing what must be done in their sphere to enable any duties whatever to be discharged. Thus it shows simply that without the exercise of qualities that need not be here named again, man cannot support those dependent on him, or even himself. If it do not establish the obligation, it shows how only the obligation can be fulfilled.

Let me once more recur to physiology for an illustration. The duty of preserving one's own life and health will not be gainsaid. Physiology enforces this duty by showing how it must be fulfilled. But, if one's mother were to fall into the sea, are we to be told that physiology forbids the son to leap into the waves, and even peril his own health and life in the effort to save her who gave him birth? Physiology does not command this, it is true; this is not its sphere; but this, at least, it does: it teaches and trains to the fullest development of strength and activity, that so they may be equal for every exigency—even one so terrible as this; and so precisely with Economic Science.

Again, we are told it discourages marriage:

"Look at me, ma'am," says Mr. Bitzer. "I don't want a wife and family. Why should they?"

"Because they are improvident," said Mrs. Sparsit.

"Yes, ma'am, that's where it is. If they were more provident, and less perverse, ma'am, what would they do? They would say, 'While my hat covers my family,' or 'While my bonnet covers my family,' as the case might be, ma'am, 'I have only one to feed, and that's the person I most like to feed.'" —(p. 336.)

Does this mean that men or women ought to rush blindly into the position of parents, without thinking or caring whether

their children can be supported by their industry, or must be a burden on that of society at large? If not, on what ground is prudent hesitation, in assuming the most solemn of all human responsibilities, a subject for ridicule and censure? Is the condition of the people to be improved by greater or by less laxity in this respect?

But not merely are we told that this teaching (which, by the way, scarcely exists in any but a very few schools), tends to selfishness, and the merging of the community in the individual; it has, it seems, also, a quite opposite tendency to merge the individual in the community, by accustoming the mind to dwell wholly on *averages*. Thus, if in a city of a million of inhabitants twenty-five are starved to death annually in the streets, or if of 100,000 persons who go to sea 500 are drowned, or burned to death, we are led to believe that Economic Science disregards these miseries, because they are exceptional, and because the average is so greatly the other way! Now, though in comparison of two countries, or two periods, such averages are indispensable, Economic Science practically teaches everywhere to analyse the collective result into its constituent elements—in a word, to *individualize*. It teaches, for example, that every brick, and stone, and beam of this building, of this street, of this city, has been laid by some individual pair of hands; and it urges every man to work for himself, and to render his own industry ever more productive, surely not to rest in idle contemplation of the average of industry throughout the land. It is his duty to swell, not to reduce that average. So with prosperity. I am quite unable to see what tendency the knowledge of that average can have to discourage the effort to increase it. Besides, it is a fundamental error to confound mere statistics with Economic Science, which deals with *facts* only to establish their connexions by way of cause and effect, and to interpret them by *law*.

But were it otherwise, with what justice can economic instruction be charged with destroying imagination, by the utilitarian teaching of "stubborn facts." Why should either exclude the other? I can see no incompatibility between the two.* By all means let us have poetry, but first let us have

* On this score, I have personally no misgivings. Seventeen years ago, I delivered and published a lecture, in which I urged the exercise of the imagination, or æsthetic culture, in the youthful training of all classes. My convictions are at least as strong now as they were then.

our daily bread, even though man is not fed by that alone. It is the *Poet* Rogers who says, in a note to his poem on *Italy*, "To judge at once of a nation, we have only to throw our eyes on the markets and the fields. If the markets are well supplied, and the fields well cultivated, all is right. If otherwise, we may say, and say truly, these people are barbarous or oppressed." Destitution must be removed for the very sake of the higher culture. If we would have the tree fling its branches widely and freely into the upper air, its roots must be fixed deeply and firmly in the earth. But enough of this subject, on which I have entered with pain, and only from a strong sense of duty. The public mind, alas, is not enlightened enough to render such writing harmless.

Hitherto I have spoken only of those great principles, and the duties flowing therefrom, which pervade the whole subject. But if these principles are the most comprehensive, there are very many others which, in the practical affairs of life, it is most important thoroughly to understand, and which it is the peculiar business of Economic Science to expound. It is an error to suppose that in matters touching men's "business and bosoms," even though of daily and hourly recurrence, instruction is not needed, and that "common sense" is a sufficient guide. Alas, *common* sense is widely different from *proper* sense. It is precisely in these subjects that error most extensively prevails, and that it is most pernicious where it does prevail. In matters far removed from ordinary life and experience, pure ignorance is possible, perhaps; and, in comparison, little mischievous. But in those which concern us all and at all times, it is alike impossible to be purely ignorant and to be ignorant with impunity. If the mind have not right notions developed at first, it will certainly have wrong ones. Hence we may say of knowledge what Sheridan Knowles says of virtue: "Plant virtue early! Give the *flower* the chance you suffer to the *weed!*"

The minds of most men are a congeries of maxims, and notions, and opinions, and rules, and theories picked up here and there, now and then, some sound, others unsound, each often quite inconsistent with the rest, but which are to them identified with the whole body of truth, and which are the standard by which they try all things. This fact explains a

remark in a recent school report, that it is far easier to make this science intelligible to children than to their parents;—no doubt, just as it is easier to build on an unoccupied ground than on one overspread by ruins. And so, not only is it possible to teach this subject to the young; but it is to the young that we must teach it, if we would have this teaching most effective for good. For further evidence of the general need for this kind of instruction it suffices to look around us, and test some of the opinions prevalent lately or even now. And here there is much of interest that might be said, did time permit, of still prevailing errors regarding strikes, and machinery, and wages, and population, and protection, and taxation, and expenditure, and competition, and much more besides. But into this field my limits forbid me even to enter. Let me, however, refer you to a most admirable series of lessons on *The Phenomena of Industrial Life, and the Conditions of Industrial Success*,* which has recently appeared under the editorship of that zealous educationist, the Dean of Hereford. The appearance of this book, and the recognition of this subject in the last Report of the National School Society, are cheering signs that the omissions of past ages in our school systems on this head are not destined much longer to continue.

The programme of this lecture speaks of the importance of Economic Science to all classes. It would be a serious error to suppose that its advantage is confined wholly, or even chiefly, to those who depend on daily labour for daily bread. Even were it so, in the midst of frequent and rapid changes of position, the rich man becoming poor, as well as the poor man becoming rich, this kind of teaching would still be important for all classes. But the *capitalist* not less, it may be said even more, than the *labourer*, needs instruction. He has been styled the captain of industry; it is for him to marshal, and equip, and organize, and pay its forces, and to guide their march. Any mistake on his part must be widely injurious. The wise employment of capital is a most momentous question; for it determines the direction of the industry of millions, and affects the prosperity of all coming time. From the class of the rich, too, are our legislators chiefly chosen. To them this kind of knowledge is important just in proportion as, in their case,

* Price 2s. Groombridge, Paternoster Row.

ignorance or error is most pernicious. Of the aristocracy of our day, were old Burton living now, he would scarcely say what he said of those of his own time: "They are like our modern Frenchmen, that had rather lose a pound of blood in a single combat, than a drop of sweat in any honest labour." * The contagion of industry has spread to them; and idleness is less than ever confounded with nobility. But there is ample room for further progress. If wealth, even economically considered, involve increased responsibility, it calls the more loudly for enlightenment and guidance.

Again, on the side of expenditure, or consumption, does this subject especially concern the rich. As *supply* ever follows *demand*, it is by this that production is mainly guided. Shall it run in the direction of sensuality and self-indulgence, or shall it flow in better and more useful channels? Memorable are the words of Lord Byron in his later days in Greece:

> The mechanics and working classes who can maintain their families are, in my opinion, the happiest body of men. Poverty is wretchedness; but it is perhaps to be preferred to the heartless, unmeaning dissipation of the higher orders. I am thankful I am now entirely clear of this, and my resolution to remain clear of it for the rest of my life is immutable. †

At this most suggestive topic I can barely hint. Much beside I am forced wholly to omit. But I must not pass in total silence the claims of this subject on the attention of the other sex. Fortunately, little needs be said within this Institution, of whose audience at lectures on every subject ladies form perhaps not the smallest, and certainly not the least attentive portion. Surely I shall not be told that a superficial sketch, such as mine, is for them unobjectionable, but that the serious study of the science is, in their case, to be discountenanced. If any kind of knowledge can do harm to any living being, it is just this very superficial knowledge. It is like the twilight which, holding of day on the one hand, and of night on the other, mocks the senses with distorted appearances which thicker darkness would hide, but which a broader daylight would dispel. In truth, women have a special interest in this subject. The part they play in industrial pursuits depends much on conventional circumstances, and varies in various

* *Anatomy of Melancholy.*

† *Last Days of Lord Byron*, by W. PARRY, p. 205. 1825.

countries; but in all, their influence in the region of expenditure is vastly great. Who shall say how deeply the welfare of families and of society at large is involved in this? Again, the domain of charity is peculiarly feminine; and the benevolent impulse, ever so ready to spring up, needs to be guided to the prevention, rather than to the relief, or what is too often, in fitter phrase, the indirect increase of misery. Well does Thomas Carlyle (no friend of *the dismal science*, as he loves to call it), in his quaint, odd way, exclaim:

> What a reflection it is that we cannot bestow on an unworthy man any particle of our benevolence, our patronage, or whatever resource is ours—without withdrawing it, and all that will grow of it, from one worthy, to whom it of right belongs! We cannot, I say; impossible; it is the eternal law of things. Incompetent Duncan M'Pastehorn, the hapless incompetent mortal to whom I give the cobbling of my boots—and cannot find in my heart to refuse it, the poor drunken wretch having a wife and ten children; he *withdraws* the job from sober, plainly competent and meritorious Mr. Sparrowbill, generally short of work, too; discourages Sparrowbill; teaches him that he, too, may as well drink and loiter and bungle; that this is not a scene for merit and demerit at all, but for dupery, and whining flattery, and incompetent cobbling of every description—clearly tending to the ruin of poor Sparrowbill! What harm had Sparrowbill done me that I should so help to ruin him? And I couldn't *save* the insalvable Mr. Pastehorn: I merely yielded him, for insufficient work, here and there a half-crown, which he oftenest drank. 'And now Sparrowbill also is drinking! *

Between the Lady Bountiful of olden times, with her periodical distributions of coals and blankets, and simples and cowslip wine, who regarded the poor as her pets, her peculiar luxury, of which, did they cease to be mendicants, she would be cruelly deprived—and the Mrs. Jellyby, whose long-ranged benevolence shoots in a parabolic curve far over what is near, to descend on what is remote, hurrying past and above St. Giles or Whitechapel, and exploding on "Borrioboola Gha"; between these widely distinct forms of what is called in both alike CHARITY, there is room and there is need for women of judgment as clear as their sympathy is earnest, who can think for themselves, as well as feel for others; who shall not so do good that evil may come, but rather help the feeble to self-help, and, while they raise the fallen, look mainly to "forestalling" others "ere they come to fall."

Up to this point I have spoken solely of one class of advantages attending the teaching of Economic Science. But, as you

* *Model Prisons*, p. 24; *Latter-Day Pamphlets*, No. 2.

have been told oftener than once during this course, the teaching of every branch of knowledge has, in different degrees, two sorts of advantage: (1) in increasing man's outward resources; (2) as a means of mental discipline and inward culture. Of the second of these advantages I can now say but little. It is wholly unimportant to discuss the comparative claims of different subjects in this respect. The difference among them is, perhaps, rather of kind than of degree. Mathematics discipline one set of powers, metaphysics another; or in so far as both exercise the same powers, it is in different ways. I claim no monopoly, I arrogate no superiority. I simply assert the *educational* value of this subject, without prejudice to any other, and all the more strongly, because it has been and is so sadly neglected. Surely, those subjects which have the most direct and powerful bearing on human well-being, and which treat of some of the most important relations between man and man, cannot be educationally less efficient than other studies which concern man less closely and directly. And I leave it to you who have heard even this most imperfect and hurried exposition, to judge whether it can fail to be a most improving mental exercise to sift such questions as the relations and laws of price, of capital and labour, and wages and profits, and interest and rent, and to trace to their origin, and follow to their results, the fluctuations affecting all these in our own and other countries, in our own and other times. As regards the other sex, on this ground, at least, there can be no doubt, even if the former admitted of hesitation. To women and to men, this discipline is alike valuable: for women it is even more necessary; for men are inevitably brought more into contact with the world and its affairs, and so have the defects of their early teaching in part corrected. It is well, at the same time that the understanding is exercised, to foster an interest in human welfare by an enlarged comprehension of its conditions. We hear little now of the policy or propriety of confining woman's studies to superficial accomplishment. It were an error, scarcely less serious, to confine them to inquiries which leave the individual isolated from the race.

Let me not, in conclusion, be supposed to ignore, because I would not invade, other, and (by common consent) the most sacred grounds on which the moral aspects of this subject may

be viewed. Let the duties on which human welfare, even industrially considered, is dependent, be enforced elsewhere, by reasons too high for discussion here. But surely this ground, at least, is in common to religious sects of every variety of creed and name. Surely it is a solemn and cogent consideration that the very fabric of our social being is held together by moral laws, and that the man who violates them outlaws himself, as it were, from the social domain, and rouses into armed hostility a thousand agencies which might and would otherwise fight upon his side. Not only the profligate, the gambler, the swindler, and the drunkard, but the idle, the reckless, the unpunctual, the procrastinating, find here a bitter but wholesome condemnation; and the very science which is ignorantly charged with fostering selfishness, teaches every man to estimate his labours by their tendency to promote the general good. Nor is it unimpressive, as regards even what Wordsworth so finely calls

The *unreasoning* progress of the world,*

to watch how the social plan is carried on by the composition of so many volitional forces, each bent on its own aims. "The first party of painted savages," it has been well said, "who raised a few huts upon the Thames, did not dream of the London they were creating, or know that in lighting the fire on their hearth they were kindling one of the great foci of Time." . . . "All the grand agencies which the progress of mankind evolves are formed in the same unconscious way. They are the aggregate result of countless single wills, each of which, thinking merely of its own end, and perhaps fully gaining it, is at the same time enlisted by Providence in the secret service of the world." † If law be indeed the expression of an intelligent and benevolent will, reverence and obedience towards the great Lawgiver must surely be fostered (mark, I do not say *created*) by the study of His laws, and the contrasted results of their observance and their violation. And, finally as regards that practical religion whose testing fruit is effort for the good of man—a study which shows so clearly that human

* "In the unreasoning progress of the world
A wiser spirit is at work for us,
A better eye than ours."—WORDSWORTH.

† James Martineau.

welfare is involved in obedience to fixed laws, and that obedience, to be reliable, must be based on knowledge of their existence and authority, must surely stimulate the extension of this needful knowledge among all classes of the people. In this light, it is abundantly apparent that, sacred as is the duty of acquiring knowledge, the duty of diffusing it is not less sacred; and that knowledge is no exception to the divine precept—"It is more blessed to give than to receive."

APPENDIX TO p. 177

Political Economists, with but slight exception, have neglected to urge universal Teaching and Training in the Economic laws as THE condition indispensable for the most beneficial working of those laws themselves. Misled by physical analogies, e.g. between the relation of supply and demand, and the rising and falling of water as it *seeks* its level, they have failed practically to recognize that human motives and human will are ever the keystone in the arch which bridges over the interval between economic cause and effect. To Mr. Samuel Bailey belongs (so far as I know) the credit of having first clearly established this truth—simple as it is—in his Essay on *The Uniformity of Causation*, published in 1829. The same writer, in his *Discourse on Political Economy* (1852, p. 109), thus writes: "The object of Political Economy is not to ascertain all the laws by which wealth is produced and distributed, but only one class of them, namely, *the moral or mental laws*, or in other words, *those laws of human nature* on which the economical condition of nations depends." It may be doubted, however, whether even Mr. Bailey has sufficiently insisted on the great practical inference from his own doctrine—the necessity, for all men—of instruction in the nature of those laws. Yet here lies the answer to those who point to the manifold misery coincident with our civilization, whether they content themselves (like Mr. Carlyle) with angry protests against "Laissez faire, laissez aller," or go on, with the French and other Socialists to build up schemes for the entire reconstruction of the Economic World—schemes which would substitute centralized compulsion for individual agency, separate or combined, with a tendency more of less direct, more or less avowed, to Communism (or the abolition of property and of family), as their ultimate results. The ignorant abuse of human freedom, however, is a reason why men should be instructed, not why they should be enslaved. Let but enlightenment keep pace with liberty, and it will be found that intelligence within will succeed where compulsion from without must fail; and that the free action of the instructed individual is the true guarantee for the well-being of the community. To reduce this conviction to practice no one has yet done so much as Mr. William Ellis—the munificent patron of the Birkbeck Schools.* No one has laboured so zealously as he

> "To render with *these* precepts less
> The sum of human wretchedness,
> And *strengthen* MAN *with his own mind.*" †

* See *Education as a Means of Preventing Destitution*, etc., by WILLIAM ELLIS, Author of *Outlines of Social Economy*, etc. London: Smith and Elder. 1851.

† BYRON'S *Prometheus*

PRINTED AT THE COMPLETE PRESS, WEST